REPORT

ON THE

PHYSICAL AND AGRICULTURAL FEATURES

OF THE

STATE OF CALIFORNIA,

WITH A DISCUSSION OF

THE PRESENT AND FUTURE OF COTTON PRODUCTION IN THE STATE;

ALSO,

REMARKS ON COTTON CULTURE IN NEW MEXICO, UTAH, ARIZONA, AND MEXICO.

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PART II.

MAP.

INTRODUCTORY LETTER.

The state of California has until recently been considered simply as a great mining country by the people of the states east of the Rocky mountains, and comparatively little thought or attention has been given to any other capabilities it might possess. The state has, however, risen rapidly in agricultural importance, and her mining enterprises are being overshadowed by the immense farming industries, to which the exceptionally genial climate and fertile soils of her broad valleys and foot-hills are so admirably adapted. It has, therefore, been thought advisable to give it a more extended description than would seem warranted by the small amount of cotton that has been produced within her borders; the more so as the state is but slightly represented in the special investigations of the Tenth Census.

FRANCIS A. WALKER.

LETTER OF TRANSMITTAL.

BERKELEY, CALIFORNIA, *June* 1, 1883.

To the SUPERINTENDENT OF CENSUS.

DEAR SIR: I transmit herewith a report on the agricultural features and cotton production of the state of California, including descriptions of the individual counties, as well as of the regions; the result of the joint labors of Dr. R. H. Loughridge and myself.

Among the states included in the reports on cotton production California stands in a peculiar position, and at first sight the insignificant number of bales of the staple produced within the census year would hardly seem to entitle the state to be counted among those deserving a detailed description in this connection. As a matter of fact, however, this condition of things must properly be accounted as temporary and accidental; for cotton has been successfully grown within the state all the way from the Mexican boundary to Shasta county, and the staple produced has, on the whole, proved to be of peculiar excellence. The restricted area now given to its cultivation is the concurrent result of many causes, chief among which is the distance from any but a home market, which renders competition with the Gulf states in any other sphere impracticable. In the absence of cotton-mills, the home market has been restricted to the amount consumed by the woolen-mills within the state for the manufacture of mixed fabrics. Again, the predominance acquired at the outset by the culture of wheat and other food crops, and, in later years, by the culture of the grape and certain other fruits of which California has almost a monopoly in the United States, naturally tended to keep down the culture of a staple in the production of which there is such formidable competition by the Gulf states on the one hand and by India on the other.

Since, however, the production for the home market has steadily been maintained and has proved profitable, it is legitimate to infer that whenever, by the establishment of cotton factories on the coast, the local demand shall increase, cotton production will do the same.

There are, however, other causes that tend to commend cotton culture to the California farmer, viz, its relations to the peculiarities of the soil and climate, especially of the great valley. These points are discussed in detail under the proper heads in the body of this report, and they are sufficiently strong to render it probable that cotton culture will rapidly increase hereafter in the state.

The compilation of reliable descriptions of the several regions and counties of California has been beset with unusual difficulties. In the case of other states we have in most cases had the basis of a state survey, or of somewhat extensive personal explorations made under the auspices of the Census Office. In the case of California, the latter source has, for cogent reasons, been restricted to three short excursions made by myself to the southern and northern portions of the great valley and one by Mr. Herman Partsch to the region of the Salinas valley. The volumes of the California state survey are almost totally barren of information on agricultural topics, and even that relating to the topographical features can be utilized mainly as furnishing links in the chain of broader evidence. In this respect the report unfortunately does not stand alone among those of state surveys; but in consequence of the stoppage of the work in 1872 probably much of the practical matter has thus far remained unpublished. Since my arrival in the state (1875) I have vainly endeavored to revive at least the agricultural portion of the survey; but the failure to obtain from the legislature any funds applicable to field-work has compelled me to remain content with such information as could be obtained through correspondence and from specimens of soils, rocks, etc., transmitted by interested persons, for examination and report by the agricultural department of the

University of California, under a small provision made therefor by the university. In the course of time this work has furnished important information regarding the composition of the soils of the state; but little of a systematic character could be done until, upon the request of the Superintendent of Census, the authorities of the Central Pacific railroad, under the initiative of the late B. B. Redding, then in charge of its land-office, detailed an intelligent engineer, Mr. N. J. Willson, to collect soil specimens from the several stations on the main lines in the great valley from Redding to Bakersfield, and thence through Los Angeles and San Bernardino counties to Yuma. These specimens, numbering about 350, and the notes accompanying them at least from the southern division, have been the source of a great deal of important information, as will be seen from the abstracts added to the descriptions of the southern valley counties. Mr. Willson's notes from the northern part of his route were unfortunately not received. Of these specimens, and of others collected by myself and Mr. Partsch, twelve representative ones were selected for analysis, the work being done at the expense of the Census Office. Subsequently a larger number were analyzed, in the course of the regular work of the agricultural department of the university, in time for introduction into this report.

A number of other soils, with accompanying reports on the regions of their occurrence, were also received, in response to a circular issued by a commission informally constituted in advance of expected legislative action on the representation of California at the Paris exhibition of 1879. The legislative support was refused, and the reports, some of which were quite lengthy and exhaustive, remained unused until now. Abstracts of them have been added to the descriptions of the counties concerned.

Apart from these direct sources of information, such publications heretofore made as include descriptions of the whole or parts of the state—books, pamphlets descriptive of counties, and newspaper articles—have been drawn upon, and doubtful or irrelevant statements have been carefully eliminated as far as possible. This work has been a matter of no little difficulty and patient research, and has almost wholly fallen to the part of Dr. Loughridge. It is not a little singular how few of these descriptions, purporting to give the agricultural features for the benefit of possible settlers, do actually convey a definite idea of the country described. In the great majority of cases the writers deal largely in generalities concerning the results of farming operations, leaving the aspect of the country, the kinds of soil and their several areas of occurrence, and other matters of first interest, to mere conjecture or inference; a practice in which, as I have reason to know, California writers do not stand alone. To gather the natural facts from the mass of miscellaneous statements and combine them into a connected picture is often arduous work, and cannot always be successful in the absence of some personal knowledge. Still, such as they are, the descriptions hereinafter given will probably convey a better and more generally correct conception of the features of California than has heretofore been given to the public.

Prominent among the sources of information drawn upon are the following published works:

The Natural Wealth of California, by T. F. Cronise. 1868.

The Resources of California, by Theo. S. Hittell. 1874.

California As It Is, by seventy leading editors and authors. Published by the San Francisco Call Company. 1882.

Report of the Geological Survey of California, by J. D. Whitney. Geology. 1865.

The above are works of a general character, covering to a greater or less extent the entire state. The following treat only of special parts or topics:

Reports of the State Engineer (William Hammond Hall) on drainage, improvement of rivers, the flow of mining detritus, and the irrigation of the plains. Sacramento, 1880. This is a most important document, from which the greater part of the data regarding the rivers and irrigation in the San Joaquin valley and in the Los Angeles region is derived and is largely literally copied. Important data regarding the soil areas in the latter region has also been directly furnished from the state engineer's office for the agricultural map.

Reports of the Agricultural Department of the University of California for 1877, 1879, 1880, and 1882. From these is extracted nearly all the matter relating to the character and composition of soils, alkali soils, and irrigation waters.

Report on the Climatic and Agricultural Features and the Agricultural Practice and Needs of the Arid Regions of the Pacific Slope, by E. W. Hilgard, T. C. Jones, and R. W. Furnas; made under the direction of the Commissioner of Agriculture, 1882. The portions of this report relating to climate, irrigation, and other general topics have, to a considerable extent, been recast for the present one.

For the tables of rainfall and temperatures we are largely indebted to the observations made under the auspices of the Central Pacific railroad, which have been conveniently tabulated by the *Pacific Rural Press.*

Besides the above, numerous locally published "county descriptions" have been utilized, as also letters from correspondents found in the columns of the *Pacific Rural Press*, the *San Francisco Bulletin*, and other transient publications and county papers. Special points have also been elucidated by direct correspondence and verbal inquiry. It is, of course, almost impossible to give credit separately to all these numerous sources, and it has only been done where literal extracts have been made.

For the soil map accompanying this report the first basis has been the altitude map by Mr. Henry Gannett, 1877. Its outlines have, however, been materially modified at many points for our purposes from information obtained from detailed maps of some of the counties, as well as from personal observation. These county maps, for the inspection of sets of which we are indebted to the California Immigration Association and the Grangers' Bank, of San Francisco, have supplied many valuable data. The maps of the geological survey have also been fully utilized.

The arrangement of subjects in this report is substantially the same as in those preceding it, viz: first the tables of population and production, which in this case show less of actual cotton production than of the great variety of crops grown; next, a general summary of the physico-geographical and climatic features, followed by the general description of the agricultural regions and history and discussion of cotton production in California, forming Part I. Part II includes the descriptions of counties, while the cultural details, usually placed under Part III, are here included under the discussion terminating Part I, in which connection they are most readily understood.

All of which is respectfully submitted.

E. W. HILGARD.

TABULATED RESULTS OF THE ENUMERATION.

AREA, POPULATION, TILLED LAND, AND LEADING CROPS.

AREA, POPULATION, TILLED LAND, AND LEADING CROPS OF CALIFORNIA.

Counties.	Land area.	POPULATION.		TILLED LAND.			ACREAGE AND PRODUCTION OF LEADING CROPS.								Vine-yards.
		Total.	Average per square mile.	Per cent. of area.	Acres.	Acres per square mile.	Wheat.		Barley.		Corn.		Oats.		
							Acres.	Bushels.	Acres.	Bushels.	Acres.	Bushels.	Acres.	Bushels.	Acres.
	Sq. mls.														
The State	155, 980	864, 694	5. 5	6. 6	6, 602, 102	42. 4	1, 832, 429	29, 017, 707	586, 350	12, 463, 561	71, 781	1, 993, 325	49, 947	1, 341, 271	35, 539
GREAT VALLEY REGION.															
Butte	1, 720	18, 721	10. 9	27. 7	304, 677	177. 1	127, 189	2, 244, 776	23, 288	516, 474	1, 325	31, 210	418	13, 700	570
Colusa	2, 500	13, 118	5. 2	40. 8	653, 016	261. 2	261, 381	4, 537, 504	39, 930	899, 558	851	15, 735	176	3, 600	14
Yuba	700	11, 284	16. 1	24. 7	110, 839	158. 3	28, 134	359, 967	11, 057	218, 458	603	12, 220	1, 461	23, 210	618
Sutter	580	5, 159	8. 9	46. 3	171, 856	296. 3	74, 338	1, 205, 883	14, 830	365, 086	1, 596	28, 935	243	5, 916	169
Yolo	940	11, 772	12. 5	46. 4	278, 983	296. 6	115, 369	2, 086, 550	18, 320	519, 479	714	10, 090	55	1, 480	757
Solano	940	18, 475	19. 7	46. 3	278, 596	296. 3	107, 588	2, 042, 533	32, 222	571, 493	443	16, 685	127	2, 015	1, 638
Sacramento	1, 000	34, 390	34. 4	47. 6	304, 627	304. 6	44, 123	804, 631	30, 547	650, 448	3, 928	149, 550	871	22, 745	1, 938
San Joaquin	1, 360	24, 340	17. 9	52. 9	460, 342	338. 4	201, 461	3, 529, 511	32, 669	796, 409	2, 333	68, 890	130	2, 820	674
Stanislaus	1, 420	8, 751	6. 2	45. 9	417, 511	294. 0	172, 445	1, 642, 892	19, 550	312, 882	378	13, 655	....	....	99
Merced	2, 280	5, 656	2. 5	19. 0	277, 689	121. 7	67, 975	296, 308	10, 181	88, 036	574	15, 715	25	30	178
Fresno	8, 000	9, 478	1. 2	5. 6	291, 087	36. 3	20, 474	190, 923	9, 504	118, 527	414	10, 053	9	205	471
Tulare	5, 610	11, 281	2. 0	5. 6	200, 650	35. 7	28, 131	371, 081	3, 661	69, 200	2, 535	46, 255	6	160	309
Kern	8, 160	5, 601	0. 7	1. 2	61, 497	7. 5	6, 887	85, 682	6, 151	119, 571	1, 694	35, 046	80	2, 400	68
Total	35, 210	178, 035	5. 5	16. 9	3, 811, 370	108. 2	1, 255, 495	19, 398, 235	251, 928	5, 245, 621	17, 388	454, 039	3, 601	78, 281	7, 503
LOWER FOOT-HILL REGION.															
Shasta	4, 000	9, 492	2. 3	2. 1	55, 915	13. 9	6, 267	90, 610	6, 762	87, 308	59	1, 590	677	22, 039	113
Tehama	3, 060	9, 301	3. 0	13. 8	270, 441	88. 3	84, 254	1, 386, 228	14, 967	261, 838	24	750	298	9, 114	39
Nevada	900	20, 828	21. 0	4. 6	25, 207	25. 6	304	3, 235	543	10, 682	32	665	1, 165	26, 871	107
Placer	1, 480	14, 232	9. 6	10. 8	101, 923	68. 8	11, 751	183, 547	5, 594	68, 275	160	4, 879	878	14, 524	1, 036
El Dorado	1, 800	10, 683	5. 9	2. 9	33, 949	18. 8	1, 360	20, 777	1, 187	22, 911	13	414	57	1, 168	1, 415
Amador	540	11, 384	21. 1	10. 6	36, 785	68. 1	2, 886	48, 323	3, 201	101, 054	1, 191	40, 695	31	822	580
Calaveras	980	9, 094	9. 3	4. 7	29, 414	30. 0	807	16, 256	1, 926	47, 294	206	7, 295	13	330	328
Tuolumne	1, 980	7, 848	4. 0	1. 9	23, 861	12. 0	4, 055	62, 824	2, 558	41, 618	24	373	69	1, 885	418
Mariposa	1, 560	4, 339	2. 8	1. 5	15, 125	9. 6	337	4, 476	1, 314	26, 239	30	720	12	255	43
Total	16, 390	97, 196	6. 0	6. 8	592, 620	36. 2	111, 521	1, 825, 276	38, 002	666, 564	1, 739	57, 381	3, 195	77, 008	4, 079
SOUTHERN REGION.															
Los Angeles	4, 750	33, 381	7. 0	6. 4	195, 055	41. 0	29, 349	316, 042	38, 823	405, 708	22, 771	752, 104	78	1, 470	4, 161
San Bernardino	23, 000	7, 786	0. 3	0. 2	25, 601	1. 1	2, 558	45, 582	4, 076	82, 563	774	23, 136	....	....	1, 215
San Diego	14, 600	8, 618	0. 6	0. 4	38, 247	2. 6	8, 929	60, 650	3, 573	45, 330	440	8, 017	77	958	224
Total	42, 350	49, 785	1. 2	0. 9	258, 903	6. 1	40, 836	422, 274	46, 472	533, 601	23, 985	783, 257	155	2, 42[illegible]	5, 600
COAST RANGE REGION.															
South of the bay region.															
San Francisco	40	233, 959	5, 849. 0	8. 9	2, 298	57. 4	....	....	349	3, 500	....	....	44	440	1
San Mateo	440	8, 669	19. 7	26. 3	73, 986	168. 1	10, 767	219, 084	16, 705	349, 644	118	1, 380	7, 376	132, 473	39
Contra Costa	800	12, 525	15. 6	45. 5	232, 794	290. 9	71, 870	1, 267, 016	19, 674	501, 880	55	1, 360	1, 280	37, 455	325
Alameda	660	62, 976	95. 4	47. 4	200, 360	303. 5	36, 032	620, 758	39, 075	1, 218, 820	1, 139	37, 573	1, 458	32, 766	344
Santa Clara	1, 400	35, 039	25. 0	18. 5	166, 184	118. 7	38, 623	648, 055	29, 613	716, 860	261	10, 391	260	4, 771	1, 532
Santa Cruz	420	12, 802	30. 5	15. 0	40. 205	95. 7	12, 060	291, 049	5, 945	176, 804	1, 768	43, 873	934	21, 513	346
Monterey	3, 520	11, 302	3. 2	7. 5	168, 862	48. 0	69, 022	779, 286	35, 426	825, 550	498	14, 978	3, 363	88, 362	10
San Benito	990	5, 584	5. 6	14. 2	90, 590	91. 5	32, 223	837, 271	10, 469	192, 462	299	6, 720	41	846	62
San Luis Obispo	3, 460	9, 142	2. 6	8. 0	177, 598	51. 3	10, 618	173, 531	9, 658	205, 869	458	13, 503	937	13, 405	56
Santa Barbara	2, 200	9, 513	4. 3	7. 7	108, 749	49. 4	18, 492	265, 955	13, 598	245, 667	3, 167	123, 795	24	330	77
Ventura	1, 690	5, 073	3. 0	7. 5	81, 107	47. 9	8, 479	113, 497	28, 171	551, 289	9, 121	148, 485	40	300	134
Total	15, 620	406, 584	26. 0	13. 4	1, 342, 733	85. 9	308, 186	5, 215, 502	208, 683	4, 983, 345	16, 874	402, 058	15, 757	332, 661	2, 926
North of San Pablo bay.															
Marin	580	11, 324	19. 5	5. 8	21, 357	36. 8	2, 603	55, 520	1, 499	37, 554	....	....	1, 031	26, 937	40
Sonoma	1, 520	25, 926	17. 0	18. 4	178, 954	117. 7	30, 820	742, 123	11, 126	256, 007	5, 961	158, 829	2, 615	68, 685	8, 540
Napa	840	13, 235	15. 8	15. 1	81, 045	96. 4	33, 653	611, 445	5, 753	130, 844	1, 664	41, 722	1, 014	22, 250	6, 071
Lake	1, 100	6, 596	6. 0	5. 5	38, 564	35. 1	8, 296	173, 842	4, 551	124, 300	755	19, 277	352	10, 243	54
Mendocino	3, 780	12, 800	3. 4	2. 4	58, 164	15. 3	8, 899	166, 666	3, 544	101, 829	884	20, 526	2, 843	80, 288	77
Trinity	2, 490	4, 999	2. 0	0. 3	4, 830	1. 9	1, 071	14, 185	14	220	30	980	165	3, 626	3
Humboldt	3, 750	15, 512	4. 1	2. 9	69, 025	18. 4	3, 437	84, 532	2, 629	94, 848	624	16, 313	8, 817	354, 785	10
Del Norte	1, 540	2, 584	1. 7	1. 0	10, 678	6. 9	56	995	54	1, 530	42	1, 710	200	4, 830	4
Total	15, 600	92, 976	5. 9	4. 6	462, 617	29. 7	97, 835	1, 849, 308	29, 170	747, 132	9, 960	259, 357	17, 037	571, 644	15, 399

AREA, POPULATION, TILLED LAND, AND LEADING CROPS OF CALIFORNIA—Continued.

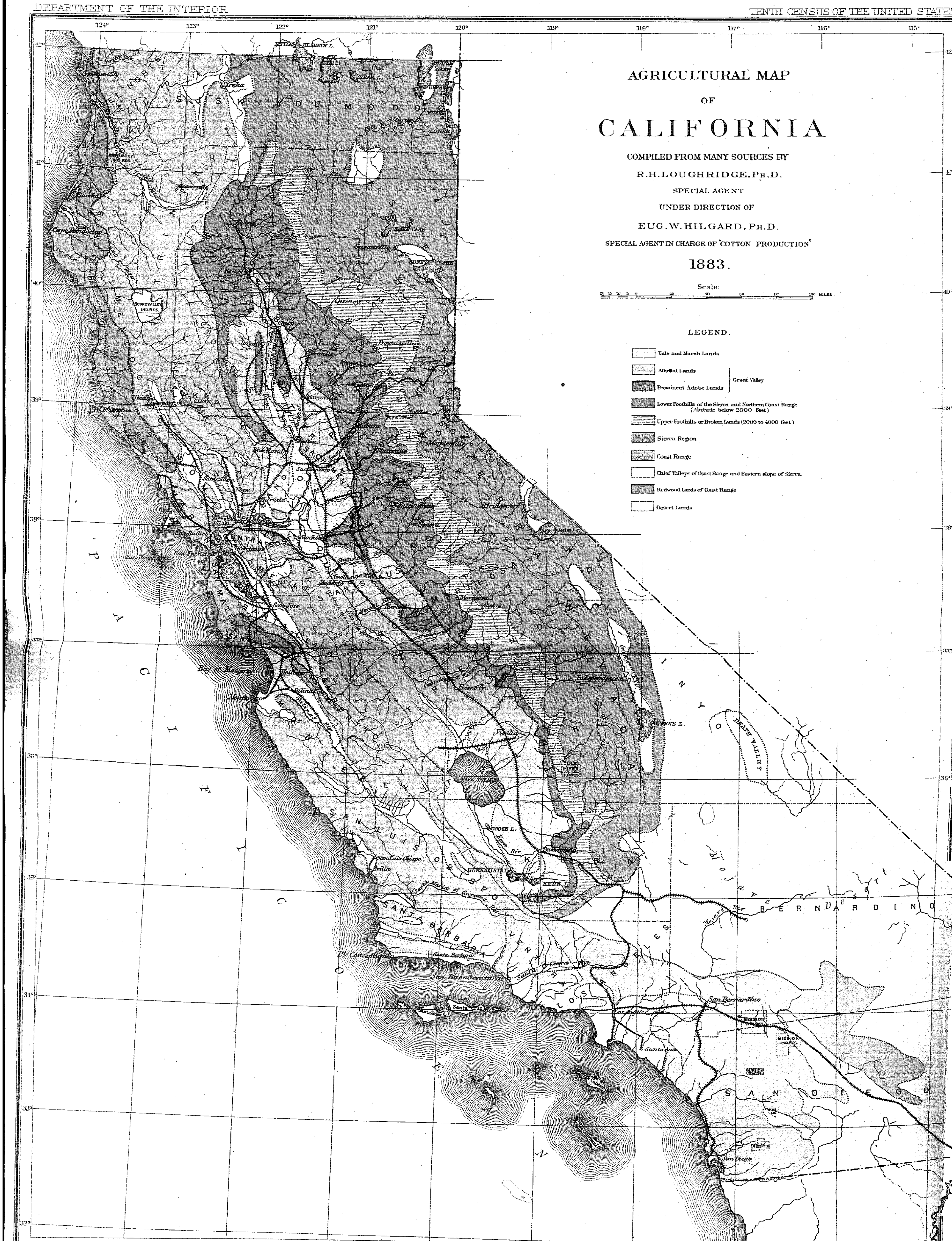
Counties.	Land area.	POPULATION.		TILLED LAND.			ACREAGE AND PRODUCTION OF LEADING CROPS.								Vineyards.
							Wheat.		Barley.		Corn.		Oats.		
		Total.	Average per square mile.	Per cent. of area.	Acres.	Acres per sq. mile.	Acres.	Bushels.	Acres.	Bushels.	Acres.	Bushels.	Acres.	Bushels.	Acres.
HIGHER FOOT-HILL AND SIERRA MOUNTAIN REGION.	Sq. mls.														
Siskiyou	5,660	8,610	1.5	1.4	50,777	9.0	6,330	98,370	3,508	114,013	112	3,015	3,268	106,350	10
Modoc	4,260	4,399	1.0	0.7	20,017	4.7	4,301	78,335	3,956	91,325	18	440	774	20,883	......
Lassen	5,000	3,340	0.7	0.9	29,161	5.8	4,773	75,361	1,950	37,073	15	3[illegible]0	1,465	33,126	......
Plumas	2,760	6,180	2.2	0.9	15,791	5.7	1,129	21,217	16	535	....	....	2,574	87,707	......
Sierra	880	6,623	7.5	1.1	6,269	7.1	308	689	391	1,172	....	....	1,082	2,320	......
Alpine	730	539	0.7	0.2	790	1.1	179	2,936	113	3,410	8	235	236	5,985	......
Mono	3,400	7,499	2.2	0.1	1,190	0.3	11	200	295	3,925	....	....	12	250	......
Inyo	8,120	2,928	0.3	0.3	13,864	1.7	1,525	30,004	1,686	35,845	1,682	33,213	791	22,538	22
Total	30,810	40,118	1.3	0.7	137,859	4.5	18,556	307,112	12,005	287,298	1,835	37,233	10,202	279,249	32

PART I.

PHYSICO-GEOGRAPHICAL AND AGRICULTURAL FEATURES

OF THE

STATE OF CALIFORNIA.


AGRICULTURAL MAP
OF
CALIFORNIA
COMPILED FROM MANY SOURCES BY
R.H. LOUGHRIDGE, PH.D.
SPECIAL AGENT
UNDER DIRECTION OF
EUG. W. HILGARD, PH.D.
SPECIAL AGENT IN CHARGE OF "COTTON PRODUCTION"
1883.
Scale
LEGEND.
Tule and Marsh Lands
Alluvial Lands
Prominent Adobe Lands
Great Valley
Lower Foothills of the Sierra and Northern Coast Range (Altitude below 2000 feet)
Upper Foothills or Broken Lands (2000 to 4000 feet)
Sierra Region
Coast Range
Chief Valleys of Coast Range and Eastern slope of Sierra.
Redwood Lands of Coast Range
Desert Lands
PACIFIC OCEAN
SAN DIEGO
SAN BERNARDINO
LOS ANGELES
INYO
DEATH VALLEY
Julius Bien & Co. lith.

OUTLINE OF THE PHYSICAL GEOGRAPHY OF THE STATE OF CALIFORNIA.

The state of California lies between the parallels of 32° 30′′ and 42° north latitude, thus stretching through nine and a half degrees of latitude, corresponding to the difference on the Atlantic coast between Edisto inlet, South Carolina, and cape Cod, Massachusetts. Its northern third lies between 120° and 124° 26′ west longitude, the most westerly point being cape Mendocino, whence the coast trends southeastward, with a westerly convexity, toward San Diego bay. Between the extreme northwest and southeast corners the direct distance is 775 miles. The maximum width (between point Concepcion and the north end of the Amargosa range in Nevada) is 235 miles, and the minimum width (between the Golden Gate and the southern end of lake Tahoe) 148 miles. The total area of the state is 158,360 square miles. Its land area alone is 155,980 square miles, being second only to Texas among the states and territories as now defined.

It is obvious that on this vast area the diversity of climates and of soils must be very great, and that only a very general outlining of these can be attempted within the limits of this report.

TOPOGRAPHY AND DRAINAGE.—The climates of the several portions of the state are so directly dependent upon its topographical features that an outline of these must, of necessity, precede any other discussion.

The two prominent features, extending through nearly the entire length of the state, are the snow-capped range of the Sierra Nevada on the eastern border and the low Coast range, or rather belt of ranges, bordering the sea-coast on the west. Between the two lies the great valley of California, drained from the northward by the Sacramento, and from the southward by the San Joaquin river, and these, uniting near the middle of the length of the valley, pass westward through the narrow strait of Carquines into San Francisco bay, and thence through the Golden Gate into the Pacific ocean. These two rivers receive nearly all their water from the Sierra Nevada, the streams flowing landward from the Coast range being insignificant. The main drainage of the Coast range is to seaward through many small rivers bordered by fertile valleys. The immediate coast is mostly abrupt and rocky, and frequently mountainous.

The maximum width of the great valley occurs opposite the outlet of the rivers, and in its southern portion, near the south end of Tulare lake, where it is over 60 miles. In its middle part the distance between the foot-hills of the two ranges averages about 40 miles; but to the northward these ranges gradually converge, the Coast range widening and becoming higher, while the Sierra narrows and, as a whole, becomes lower, though rising locally into the Lassen peaks, and culminating, as it merges into the coast ranges, in the great volcanic mass of Shasta. Northwestward the Siskiyou mountains form a cross range of considerable elevation, an effectual natural barrier between California and Oregon, while northeastward lies the barren "lava-bed" plateau, with its numerous lakes. The great valley may be considered as terminating northward at Red Bluff, Tehama county, although more or less valley land, but of a different character, occurs along the Sacramento river as far north as Redding, Shasta county.

Southward the termination is much more definite, the Coast range and the Sierra being cross-connected, in a graceful sweep around Buena Vista and Kern lakes, by the Tejon range, beyond which to the eastward lies the great arid plateau of the Mojave desert. This range continues southward into the ranges of San Fernando, San Gabriel, and San Bernardino, all of which are often comprehended under the general but somewhat indefinite name of Sierra Madre, also applied far to the southward to the mountains representing the continental divide; but it would be better to comprehend the whole under the name of the San Bernardino range. Southward of this range lies the valley or plain of southern California, most of which is within the county of Los Angeles, with an outlier in the southwestern corner of San Bernardino, and is partly screened from the direct impact of the coast winds by a low coast range, the Santa Ana mountains, which is, however, traversed by the country drainage from the higher ranges. Toward San Diego county this coast range divides into a broad belt, dotted with smaller ranges and interspersed with valleys and table-lands, about 30 miles wide from the coast inland to the Mexican boundary.

Northward of the San Bernardino range lie the great Mojave and Colorado deserts, mostly high barren plateau lands, intersected by short abrupt mountain ranges, devoid of streams, and largely composed of sandy and "alkali" soils incapable of reclamation. To the northwest from the desert region numerous short water-courses descend from the steep eastward slope of the Sierra; but, although they create some fertile valleys adapted to agriculture, their volume is very small compared to the drainage of the western slope.

GEOLOGY.—Broadly speaking, the coast ranges of California consist of Tertiary and Cretaceous strata (mostly sandstones and calcareous clay shales), almost everywhere greatly disturbed, folded, and frequently highly metamorphosed, and traversed by dikes of eruptive and upheaval-axes of rocks. In the portion north of San Francisco these are frequently covered by tufaceous and scoriaceous or crystalline lava-flows, emanating from distinct volcanic vents now extinct.

In contrast to the Coast range, the Sierra Nevada has in general a central axis of granitic or other rocks (occasionally traversed by volcanic vents), on the flanks of which lie more or less crystalline and metamorphic slates or schists of Palæozoic, Triassic, and Jurassic age with edges upturned at a high angle or sometimes vertical. Abutting against this, the proverbial "bed-rock" of the California miners, there lie on the eastern border of the great valley strata of marine deposits, mostly of the Tertiary, but northward of Folsom, Sacramento county, also of the Cretaceous age, which are but slightly disturbed, and into which the rivers flowing from the cañons of the Sierra have cut their immediate valleys, flanked by bluffs from 40 to 70 feet high. From Tuolumne county northward, on the lower foot-hills, appear immense gravel beds, mostly gold-bearing, and these are partly overlaid by eruptive or volcanic outflows and tufaceous rocks, also accounted as belonging to the Tertiary age. In the northern portion of the Sierra region the eruptive rocks become more and more prominent, covering an enormous area ("the lava-bed") in the northeastern part of the state, and, as in the Cascade range, in Oregon, forming the body of the comparatively low range upon which the volcanic cone of mount Shasta is superimposed.

Apart from the Cretaceous and Tertiary beds on the borders of the great valley, there are within the valley terraces and bench-marks showing the existence in Quaternary times of a great fresh-water lake, which was subsequently drained byt he erosion or breaking, first, of the strait of Carquines, and ultimately of that of the Golden Gate. Prior to the latter event the drainage of the great valley passed through the Santa Clara and Pajaro valleys into the bay of Monterey. Borings in the interior valley disclose materials varying from fine silts to sands and gravels, evidently deposited in the ancient lake. The latest surface deposits are, in the San Joaquin valley, mostly sandy, in the Sacramento valley more commonly clayey ("adobe"), corresponding to the composition of the coast ranges themselves, which in their interior southern portion show sandy materials more prevalently, while in the middle division clay shales are predominant, and form correspondingly heavy soils.

Since the agricultural features of California depend much more upon the topography than upon any details of geological structure a more extended discussion of the latter would be out of place here. So far as relevant to the objects of this report they will be referred to in the regional and county descriptions.

WINDS.—The prevalent winds on the California coast are from the west, the influence of the Pacific ocean thus producing a climate in which the extremes of both heat and cold belonging to the several latitudes are tempered, so that on San Francisco bay and southward to Monterey the difference between the average temperatures of summer and winter is only from 6 to 10 degrees. This equalizing effect is partly cut off from the interior valley by the Coast range, which also intercepts a portion of the moisture carried by these winds; the remainder is condensed mainly on the western slope of the Sierra Nevada, thus producing the arid continental climate of the interior plateau of Nevada. In the great interior valley the general direction of these winds is changed to "up-valley", that is, to a little west of south in the Sacramento valley and slightly west of north in that of the San Joaquin, a heavy westerly breeze blowing in, as a rule, through the joint outlet of both valleys, the straits of Carquines.

North of cape Mendocino the direction of the prevailing currents is more from north of west, but south of the cape the direction is due west or slightly south of west, forming the "summer trade winds", which set in regularly some time in May and continue, with but an occasional interruption by a "norther", until October, laden with moisture from the warm, high seas. In summer these winds strike the cold Alaskan ocean current, which comes to the surface and sets in-shore off central California, producing dense fogs, which during the summer months frequently cover the coast country for twenty out of twenty-four hours for weeks together. Beyond a slight drizzle, however, no water falls; and as the fog banks drift against and up the slopes of the Coast range they dissolve quickly before the intense heat and dryness of the summer atmosphere in the great valley beyond. The moisture absorbed by the soil of the coast belt from these fogs goes far, however, toward maintaining the growth of the hardier herbaceous as well as of woody plants, no less than that of weeds, during the season of drought.

From May to October, both inclusive, south winds are very rare, but during the winter months they prevail largely, and bring the rains upon which the success or the failure of crops depend. The winter rain-storms are usually heralded by heavy weather in Oregon or in the Shasta region, whence the rain wind works backward, so to speak, until it exhausts itself in the southern part of the San Joaquin valley, where the San Fernando range seems to form a partial weather divide, leaving the Los Angeles region more or less independent of the changes to the northward. Sometimes the rain-storm works chiefly down the coast, leaving the great valley almost dry, in which case Los

Angeles and San Diego usually get a fair proportion of its benefit. Sometimes prolonged and severe storms cover the entire state and extend far into British Columbia and Arizona. As thunder and lightning rarely form a part of the atmospheric disturbance, the rain usually falls gently and continuously, rather than in torrents, and thus chiefly soaks into the ground. Sometimes a fierce south wind drives it for a day or two, and then generally there comes a change; the wind gradually veers to the westward, then more rapidly to northwest and north, and with a heavy shower the sky clears suddenly and a "norther" sets in; though not ordinarily bringing a very low thermometer, it often feels bitingly and penetratingly cold, because of its velocity and dryness, which cause rapid evaporation. Before the "norther" the surface moisture quickly disappears, muddy roads become as rough as if frozen, and compact ground cracks after a few days. Any long prevalence of this wind is looked upon with dread at all seasons, on account of the waste of moisture which it involves even when cold. In autumn and in spring, when its temperature is higher, the young grain often withers before it, and from May to September (when it is fortunately of rare occurrence) it sometimes becomes a veritable simoon, like the breath of a hot furnace, shriveling up the grain when in milk and sometimes almost curing the standing crops into hay. To the seaward of the Coast range the "norther" is rarely of long duration, three days being its ordinary limit; but in the great valley, and especially in the valley of the San Joaquin, it is both more frequent and persistent, occasionally blighting in a week all the hopes of the grain-grower not able to resort to irrigation, and even drying the fruit on the trees. East winds are only of brief and local occurrence, being ordinarily cut off by the mountain ranges in their north and south course. They are usually the precursors of a "southwester", with rain.

Outside of the mountains the velocity of the wind rarely becomes so great as to endanger any well-constructed windmills, which are therefore very generally in use as a motive power, especially for pumping water. In the absence of electrical disturbance hurricanes and "tornadoes" are scarcely known, save in the high Sierras, where local summer thunder-storms, sometimes accompanied by cloud-bursts, may be observed among the high peaks, in curious contrast to the unclouded brightness of the sky overhanging the valley.

TEMPERATURE.—The prominent characteristic of the California coast in respect to temperature is its remarkable temperateness as compared with points similarly located on the Atlantic coast. Taking stations at or near the extreme and middle points of corresponding latitude on both coasts, the comparison stands thus:

CALIFORNIA COAST.				ATLANTIC COAST.			
Stations.	Summer.	Winter.	Year.	Stations.	Summer.	Winter.	Year.
	Degrees.	*Degrees.*	*Degrees.*		*Degrees.*	*Degrees.*	*Degrees.*
Camp Lincoln	59.5	47.2	53.9	Boston, Massachusetts	68.7	28.1	48.4
San Francisco	58.0	50.1	55.2	Cape Charles, Virginia	74.3	35.8	56.0
San Diego	69.7	54.1	62.1	Edisto, South Carolina	81.0	46.6	64.3

It will be noted that while the annual averages of corresponding points on the two coasts are not very widely different, the temperatures of summer and those of winter are very much farther apart on the eastern coast than on the western, and quite as strikingly so in the northern as in the southern portion of the respective regions. This exemption from extremes of temperature constitutes one of the great attractions of the Pacific coast.

In the interior, notably in the great valley, the seasons show greater extremes of temperature, but the greater range of the thermometer is largely offset by the fact that the dryness of the atmosphere renders the changes much less sensible than is the case in the moister air of the coast. It is thus at San Francisco, which presents the extreme of the coast climate on account of its peninsular position and the access of the sea air through the Golden Gate, those familiar with the climate making a careful distinction between the sunny and the shady side of the streets in walking, and bay windows, of necessity, take the place of porticoes or porches, which would rarely be available save in the middle of the day, while in the interior porticoes are universal, and camping out under a tree all night may be indulged in with impunity by any one during the dry season.

The table on page 10 shows more in detail the difference between the coast climates on the one hand and those of the interior on the other, it being understood that in the measure in which the valleys are screened from the immediate access of the sea air and summer fogs their climate approaches in character that of the great valley.

WESTERN OR COAST DIVISION.

Station.	County.	Elevation.	Years of observation.	General average. Summer.	General average. Winter.	General average. Year.	Monthly extremes. Summer. Maximum.	Monthly extremes. Summer. Year.	Monthly extremes. Winter. Minimum.	Monthly extremes. Winter. Year.
		Feet.		*Degrees.*	*Degrees.*	*Degrees.*	*Degrees.*		*Degrees.*	
COAST REGION, NORTH.										
Camp Lincoln*	Del Norte	......	2	59.5	47.2	53.9	....	....	....	....
Fort Humboldt*	Humboldt	50	16	58.2	47.0	52.9	....	....	....	....
Camp Wright*	Mendocino	......	6	74.7	58.8	57.8	....	....	....	....
COAST REGION, MIDDLE.										
Napa	Napa	95	5	70.3	49.3	59.9	....	....	....	....
San Francisco*	San Francisco	130	11	58.0	50.1	55.2	....	....	....	....
Oakland	Alameda	14	5	67.8	52.2	57.7	72.6	1879	49.1	1880
Martinez	Contra Costa	......	4	70.1	48.9	60.3	74.5	1878	41.9	1880
San José	Santa Clara	91	7	66.7	49.5	56.8	76.0	1879	42.2	1876
Santa Cruz	Santa Cruz	2,500	4	62.9	50.5	59.2	66.8	1881	46.2	1880
COAST REGION, SOUTH.										
Monterey*	Monterey	140	12	59.7	50.2	55.5	....	....	....	....
Salinas	......do	......	6	60.6	50.8	55.6	65.1	1877	43.9	1882
Soledad (interior)	......do	3,213	6	66.9	48.8	57.8	77.3	1876	41.8	1877
Santa Barbara†	Santa Barbara	20	7	67.9	54.1	61.4	70.0	1874-'6-'7	50.4	1875
Los Angeles	Los Angeles	265	7	73.2	55.6	64.9	83.3	1876	40.9	1882
INTERIOR VALLEY.										
Riverside (R. de Jurupa)*	San Bernardino	1,000	1½	74.2	53.2	63.7	....	....	....	....
Colton	......do	965	4	80.1	50.2	65.1	86.1	1879	44.9	1882
San Diego*	San Diego	64	20	69.7	54.1	62.1	....	....	....	....

INTERIOR AND EASTERN DIVISIONS.

Station.	County.	Elevation.	Years of observation.	General average. Summer.	General average. Winter.	General average. Year.	Monthly extremes. Summer. Maximum.	Monthly extremes. Summer. Year.	Monthly extremes. Winter. Minimum.	Monthly extremes. Winter. Year.
NORTHERN SIERRA AND LAVA BEDS.										
Fort Jones*	Siskiyou	2,570	5	71.1	34.1	52.3	....	....	....	....
Fort Bidwell*	Modoc	4,680	5	71.1	32.3	50.8	....	....	....	....
GREAT VALLEY (SACRAMENTO DIVISION).										
Redding	Shasta	556	7	81.6	47.3	63.4	87.2	1879	42.5	1880
Red Bluff	Tehama	308	10	80.8	47.5	63.7	88.9	1875	39.9	1879
Marysville	Yuba	67	10	78.7	49.5	64.4	83.9	1871	44.4	1880
Sacramento	Sacramento	30	10	71.8	48.2	60.8	76.9	1876	43.0	1880
FOOT-HILLS OF THE SIERRA.										
Auburn	Placer	1,360	11	74.1	45.4	58.6	80.5	1875	39.8	1882
HIGH SIERRA.										
Cisco	......do	5,934	11	60.9	32.7	45.2	73.1	1871	26.3	1880
Truckee	Nevada	5,819	11	61.1	27.7	43.3	70.3	1871	21.7	1874-'80
GREAT VALLEY (SAN JOAQUIN DIVISION).										
Stockton	San Joaquin	23	10	72.5	48.2	60.8	77.7	1872-'74	44.0	1879
Modesto	Stanislaus	91	8	78.2	47.8	63.2	85.3	1879	40.4	1881
Merced	Merced	171	9	79.1	49.0	63.4	85.1	1874	43.2	1876
Fresno	Fresno	292	5	84.1	51.3	67.6	90.0	1878	43.9	1882
Tulare	Tulare	282	6	83.8	45.9	64.4	95.2	1874	39.1	1874
Sumner	Kern	415	7	86.2	48.7	67.3	93.0	1875	41.9	1878

* From Smithsonian tables, compiled to December, 1870, from many sources, and represent calendar years.

† From record by Dr. L. N. Dimmick, Santa Barbara, January, 1871, to December, 1878.

All other tables are from observations of the Central Pacific railroad, published in the *Pacific Rural Press*, January, 1883. They represent season years (from July 1 to June 30).

As to the change in temperature in ascending the Sierra from the valley, the following statement is made by Mr. B. B. Redding in a paper read before the California Academy of Sciences in 1878: (*a*)

It has been found that the foot-hills of the Sierra up to the height of about 2,500 feet have approximately the same temperature as places in the valley lying in the same latitude. It has also been found that with increased elevation there is an increase of rainfall over those places in the valley having the same latitude, as, for instance, Sacramento, with an elevation above the sea of 30 feet, has an annual mean temperature of 60.5° and an average rainfall of 18.8 inches, while Colfax, with an elevation of 2,421 feet, has an annual mean temperature of 60.1° and an annual rainfall of 42.7 inches. This uniformity of temperature and increase of rainfall appears to be the law throughout the whole extent of the foot-hills of the Sierra, with this variation as relates to temperature, viz, that as the latitude decreases the temperature of the valley is continued to a greater elevation. To illustrate, approximately, if the temperature of Redding, at the northern end of the valley, is continued to the height of 2,000 feet, then the temperature of Sacramento, in the center of the valley, would be continued up to 2,500 feet, and that of Sumner, at the extreme southern end of the valley, to 3,000 feet.

It is curious to note that, as appears from Mr. Redding's statement, the lowest temperatures thus far observed at the two opposite ends of the valley, Redding and Sumner, are the same, viz, 27°.

a *Pacific Rural Press*, January 18, 1879.

It will be noted that in the southern region the difference between the summer means or between winter means, as well as between the annual means, is quite small when Santa Barbara and San Diego, both lying immediately on the coast, are compared. At Los Angeles, 20 miles inland, all these means are notably higher; still farther inland, and with increasing elevation, the summer mean rises, while the winter mean falls at Riverside, as well as more strikingly at Colton although at the latter point the annual mean is almost the same as at Los Angeles.

To convey an easily intelligible idea of some of the climatic differences indicated in the table, it may be stated that while in the great valley a few inches of snow cover the ground for a short time nearly every winter as far south as Sacramento, and snow flurries are occasionally seen even at the upper end of the San Joaquin valley, snow has fallen in the streets of San Francisco only once since the American occupation to such a depth as to allow of snowballing (which during a few hours created a state of anarchy), and only a few times has enough fallen to whiten the ground for a few minutes or hours. Hence the heliotrope, fuchsia, calla lily, and similar plants endure year after year in the open air, while at a corresponding latitude in the interior they require some winter protection. Lemon and orange trees never suffer from frost on the bay, but their fruit also rarely ripens, save in favored localities. In the interior these trees more frequently suffer from frost, but the high summer temperature matures the fruit some weeks earlier than even in the southern coast region. Cotton would, as a rule, be frost-killed in the great valley in November, while on the coast it might endure through several mild winters; but within reach of the summer fogs of the coast it fails to attain a greater height than eight or ten inches the first season, and sometimes can scarcely succeed in coming to bloom before October. Subtropical trees, which in the cotton states grow rapidly and luxuriantly, such as the crape myrtle, Paulownia, Catalpa, Mimosa (*Julibrissin*), and others, either grow very slowly or remain mere shrubs in the coast climate, while in the interior they develop as in the Gulf states. The vine flourishes near San Francisco, but fails to mature its fruit; yet it yields abundant and choice crops near San José, where the immediate access of the coast fogs is intercepted by a range of hills. It is thus obvious that, with the varying topography, the change in the direction of a valley or a mountain range, the occurrence of a gap or of a high peak in the same permitting or intercepting communication with the coast on the one hand or with the interior on the other, there exist innumerable local climates, "thermal belts," sheltered nooks, and exposed locations, each of which has its peculiar adaptations apart from soil, and the recognition and utilization of these adaptations require knowledge and good judgment and count heavily in the scale for or against success in agriculture in California.

RAINFALL.—As regards the rainfall, the prominent peculiarity throughout the state is the practically rainless summer. While it is true that rain has been known to fall in every month in the year, the average amount of precipitation during the three summer months is less than one inch in the greater portion of the state, and less than two inches even in the most favored part, viz, the counties just north of San Francisco bay. Frequently not a drop of rain falls in the interior valley and the southern region from the middle of May to November, and as the agricultural system of California is based upon the expectation of this dry weather summer rains are not even desired by the farmers at large. Northward, in the mountainous and plateau regions adjoining Oregon, the season of drought becomes shorter, as is also the case in the high Sierras, and thus there is a gradual transition toward the familiar *régime* of summer rains and occasional thunder-storms which prevails in Oregon and Washington west of the Cascade range.

Since the growing season, in the case of unirrigated lands at least, thus practically lies between November and June, and each harvest is essentially governed by the rains occurring within these limits, it is the universal and unconscious practice to count the rainfall by "seasons" instead of by calendar years; hence the current estimate of local rainfall-averages in California differs not immaterially from that of the usual meteorological tables, in which the paramount distinction between the *agriculturally* "dry" and "wet" seasons is more or less obliterated. The data hereinafter given are therefore, as a rule, "seasonal" and not "annual", and are largely those of the observations conducted along its lines by the Central and Southern Pacific railroad.

The mean annual rainfall of the greater (middle and southern) part of the state is less than 20 inches, the northern limit of that region lying between Sacramento and Marysville, in the great valley; while on the Sierras the region of rainfall between 20 and 26 inches extends as far south as the heads of King's and Kern rivers, furnishing the waters upon which depends the irrigation of the San Joaquin valley; thence southward the rain-gauge rapidly descends to 8 and 4 inches and less in the Kern valley, the Mojave desert, and the basin of Nevada.

A rapid decrease of rainfall is observed in the great interior valley. From 42 inches at Redding, at the northern end of the valley, and 24 inches at Red Bluff, 24 miles to the southward, the annual mean falls to about 19 inches at Sacramento and to 16 at Stockton. Thence southward the rainfall descends to a mean of only 10 inches at Merced, 7 at Fresno, and 4 at Bakersfield, near the southern end of the San Joaquin valley, separated only by the Tehachapi mountains from the western margin of the Mojave desert, in which the rainfall is still less.

Along the coast proper cape Mendocino bears the reputation of a kind of weather divide. Mariners expect a change of weather whenever they round this cape, and on land it marks the region where the character of vegetation begins to change rapidly from that of southern or middle California toward that of Oregon. At and immediately north of the cape the rainfall reaches an annual mean of 40 inches. A short distance southward, at point Arenas, the annual fall is 26 inches; and from 23 to 21 inches in the region of San Francisco, it falls to 16 inches at Monterey and Santa Barbara, 12 at Los Angeles, and 9 at San Diego.

Northward of cape Mendocino the rainfall increases rapidly, rising to over 70 inches in the northwestern corner of the state. Inland from the coast the increase is less rapid, but the rainfall rises at points in the Shasta region to as much as 108 inches in some years. Southward the region of rainfall exceeding 20 inches extends in the Coast range slightly farther south than in the great valley, so as to include all but the most southerly portions of the counties of Sonoma, Napa, and Marin. Southward of San Francisco again a region of more abundant rainfall includes the western Santa Clara valley, Santa Cruz mountains, Monterey bay, and the lower Salinas valley, where from 13 to 16 inches fall annually.

Ascending the Sierra from the great valley there is a rapid increase of rainfall, which, from data furnished by the records of the railroad, may be estimated at 1 inch for every 100 to 150 feet of ascent.

The following tables show more in detail the rainfall averages for representative points, the data being derived mainly from the observation made under the auspices of the Central and Southern Pacific railroad, and given for "seasons" reaching from July to June, inclusive. The data derived from the Smithsonian tables are marked by an asterisk, and refer to ordinary annual instead of seasonal means:

WESTERN OR COAST DIVISION.

Station.	County.	Elevation.	Years of observation.	Average.	Maximum.	Year.	Minimum.	Year.
COAST RANGE, NORTH.		Feet.		Inches.	Inches.		Inches.	
Camp Lincoln*	Del Norte		2	73.4				
Fort Humboldt*	Humboldt	50	16	35.9				
Camp Wright*	Mendocino		6	43.9				
COAST RANGE, MIDDLE.								
Napa	Napa	95	5	26.6	34.7	1877-'78	17.1	1881-'82
San Francisco*	San Francisco	130	10	20.7	32.1	1877-'78	8.8	1876-'77
Oakland	Alameda	14	5	20.6	29.3	1877-'78	9.6	1881-'82
Martinez	Contra Costa		4	16.1	19.7	1880-'81	12.9	1881-'82
San José	Santa Clara	91	8	11.4	19.3	1877-'78	5.0	1876-'77
Santa Cruz	Santa Cruz	2,500	5	26.4	39.2	1877-'78	22.0	1878-'79
COAST RANGE, SOUTH.								
Monterey*	Monterey	140	12	15.7				
Salinas	do		9	12.8	23.7	1877-'78	3.9	1876-'77
Soledad (interior)	do	3,213	8	7.9	15.3	1875-'76	2.7	1876-'77
Santa Barbara†	Santa Barbara	20	11	16.2	31.5	1877-'78	4.5	1876-'77
Los Angeles	Los Angeles	265	7	12.0	21.9	1875-'76	4.6	1876-'77
INTERIOR VALLEY.								
Riverside (R. de Jurupa)*	San Bernardino	1,000	1½	13.6				
Colton	do	965	6	8.2	14.5	1877-'78	5.9	1876-'77
San Diego*	San Diego	64	20	9.3				

INTERIOR AND EASTERN DIVISION.

Station.	County.	Elevation.	Years of observation.	Average.	Maximum.	Year.	Minimum.	Year.
NORTHERN SIERRA AND LAVA BEDS.								
Fort Jones*	Siskiyou	2,570	5	21.7				
Fort Bidwell*	Modoc	4,680	5	20.2				
GREAT VALLEY (SACRAMENTO DIVISION).								
Redding	Shasta	556	7	42.1	60.0	1877-'78	25.4	1881-'82
Red Bluff	Tehama	308	10	24.0	52.7	1877-'78	13.6	1874-'75
Marysville	Yuba	67	11	17.8	26.9	1873-'74	12.2	1876-'77
Sacramento	Sacramento	30	32	18.7	25.5	1875-'76	9.2	1876-'77
FOOT-HILLS OF THE SIERRA.								
Auburn	Placer	1,360	11	34.0	44.3	1875-'76	18.9	1876-'77
HIGH SIERRA.								
Cisco	do	5,934	11	60.8	82.7	1880-'81	34.1	1876-'77
Truckee	Nevada	5,819	11	34.1	44.0	1871-'72	18.0	1876-'77
GREAT VALLEY (SAN JOAQUIN DIVISION).								
Stockton	San Joaquin	23	32	15.8	20.6	1871-'72	7.2	1876-'77
Modesto	Stanislaus	91	11	9.6	13.4	1875-'76	4.3	1876-'77
Merced	Merced	171	10	9.7	12.7	1875-'76	3.2	1876-'77
Fresno	Fresno	292	5	7.0	8.9	1877-'78	4.9	1878-'79
Tulare	Tulare	282	8	6.2	10.0	1880-'81	3.1	1878-'79
Sumner	Kern	415	7	4.2	8.0	1877-'78	1.3	1878-'79

* From Smithsonian tables, compiled to December, 1870, from many sources, and represent calendar years.

† From the records of Shaw, Bowers, and Tebbetts, Santa Barbara, from 1867 to 1868.

All other tables are from observations of the Central Pacific railroad, published in the *Pacific Rural Press*, January, 1883. They represent season years (from July 1 to June 30).

Were the rainfalls of 20 inches and less distributed over the whole or even the greater part of an ordinary season of the temperate zone, it would be altogether inadequate for the growing of cereal or other usual crops of that zone; but since in California nearly the whole of it usually falls within six months (November and April inclusive), and by far the greater part within the three winter months, during which a "growing temperature" for all the hardier crops commonly prevails, it becomes perfectly feasible to mature grain and other field crops before the setting in of the rainless summer, provided only that the aggregate of moisture has been adequate and its distribution reasonably favorable. The grain sown into the dust of a summer-fallowed field begins to sprout with the first rain, and thenceforward grows more or less slowly, but continuously, through the winter; it is ready to head at the first setting in of warm weather, from the end of March to May, according to latitude, and becomes ready for the reaper from the end of May to the end of June. Once harvested, the grain may be left in the field for several months, thrashed or unthrashed, without fear of rain or thunder-storms. As a matter of course, the grain-grower may also, at his option, sow his grain at any time after the beginning of the rains, and good crops are sometimes obtained from sowings made late in February. Usually, however, the late-sown grain is cut for hay when in the milk, in April and May, for since meadows can form no part of the agricultural system, except where irrigation is feasible, the hay grasses commonly grown in the eastern states are available only to a limited extent, and wheat, barley, and oats take their place. Again, there is no strict distinction or limit between fall and spring grain, since the sowing season extends from October to February. Thus the winter months are a very busy season for the farmer in California, as he has to watch his opportunity for putting in his crop between rains. The time between laying-by and harvest is nearly filled up by gardening and haying operations. The latter are occasionally interrupted by one or two light showers, rarely enough to injure the quality of the hay. Protracted rainy spells or thunder-storms, calling for hasty gathering of the cut grain into shocks, are unknown in harvest time, as are also sprouted or spoiled grain, except when the sacked grain is left out in the fields so late as to catch the first autumn rains. It will thus be seen that midsummer finds the California grain-grower comparatively at leisure.

But while the culture of hardy plants of rapid development was the first and most obvious expedient resorted to by the American settlers in order to utilize the fertile soils of the region of rainless summers, that of selecting culture plants adapted to arid climates was the one naturally suggesting itself to the missionary padres, who brought with them from the Mediterranean region of Europe the vine, the fig, the olive, the citrus fruits, as well as from the adjacent portions of Mexico the culture of cotton, to which, however, but little attention was given by them, the growing of wool being better adapted to the temper of their native laborers. And as they relied largely on irrigation for the success of their annual crops, it was only in very extreme cases that a deficient rainfall so affected their interests as to give the fact a place in their records.

Variation and periodicity of rainfall.—While the means of rainfall given above will not vary widely when any large numbers of years are taken together, the variations from one year to another are often sufficiently great to tempt many to invest heavily in putting in crops on the chances of a favorable season, which would bring a fortune at one venture, but sometimes results in a total loss, and consequent ruin to the investor. Such cases of agricultural gambling were at one time not uncommon in the San Joaquin valley especially, the turning point of profit or loss being a single light shower at the critical time or the occurrence of a norther for a day or two. Much ingenuity has been spent in trying to forecast the weather for the season in time to determine the chances of success; but it will generally be found that the oldest citizen, if he is candid, will be far more reserved in his opinions than later comers. However steady and reliable the summer climate may be, that of a California winter is most difficult to forecast from day to day and from week to week; and, while there are certain rules that are ordinarily counted upon, the cases where "all signs fail" are very frequent and surprises are abundant. A discussion of the observations made from 1849 to 1877, by Dr. G. F. Becker, late of the University of California, and now of the United States geological survey, seems to indicate as probable a cycle of thirteen years between extreme minima or drought years, and some data I have since obtained from the records of the missions seem to confirm still further this conclusion. The first minimum within the time of the American occupation of California occurred in the season of 1850–'51, when the rainfall at San Francisco (where the mean is $23\frac{1}{2}$ inches) was only 7.4, while it had amounted to 33.1 the year before; the second minimum occurred in 1863–'64, when the rainfall at San Francisco was 10.1 inches; and the third was the season of 1876–'77, with 10 inches. The next succeeding season of minimum would be that of 1889–'90.

The following table, given by Dr. Becker, exhibits these facts, as also the probabilities deduced for the intervening years, from a discussion of the nature of the curves representing the observations: (*a*)

Observations, periodicity, and probabilities of rainfall, San Francisco.

[Tennent's gauge.]

Seasons.	Rainfall.	Seasons.	Rainfall.	Position in period.	Probabilities for the years.
	Inches.		*Inches.*		*Inches.*
1850–'51	7.40	1863–'64	10.08	I	11.50
1851–'52	18.44	1864–'65	24.73	II	20.50
1852–'53	35.26	1865–'66	22.93	III	27.40
1853–'54	23.87	1866–'67	34.92	IV	30.50
1854–'55	23.68	1867–'68	38.84	V	28.30
1855–'56	21.66	1868–'69	21.85	VI	23.30
1856–'57	19.81	1869–'70	19.31	VII	19.30
1857–'58	21.88	1870–'71	14.10	VIII	19.60
1858–'59	22.32	1871–'72	34.71	IX	25.00
1859–'60	31.22	1872–'73	18.02	X	28.20
1860–'61	19.72	1873–'74	23.98	XI	28.50
1861–'62	49.27	1874–'75	18.40	XII	28.50
1862–'63	13.62	1875–'76	26.01	XIII	19.00
Totals	308.15		307.88		309.60
1849–'50	33.10	1876–'77	10.00		

Similar tables for Sacramento and Stockton exhibit the same general features.

From information kindly furnished me by H. H. Bancroft, esq., of San Francisco, it appears in the records of the early explorers of California that the year 1805 is known as "El año del hambre" (the year of the famine), the drought having been extraordinarily severe, and nearly the same account is given of the year 1817. It will be observed that these dates indicate a period of twelve years between themselves, and that the interval from the last-mentioned date to 1877 (for whose drought years as yet no data have been found) is also divisible by the same number. It is quite intelligible that as the result of several concurrent and variable causes the period may vary between such limits as twelve and thirteen.

Should further observations confirm the existence of this definite periodicity, the forecast, even to this extent, would be of immense service to agriculture in California, since the nature of the crops, as well as their treatment, could, in a measure, be adapted to the circumstances of these "lean years". Still, the portion of the valley lying south of Stockton will always be a region of predominant irrigation, while in the northern portion a proper and intelligent co-adaptation of crops and soils can render agriculture more or less independent of that necessity. As the matter now stands, it is estimated that in the southern portion of San Joaquin county one good crop out of three may be made without irrigation, while south of Merced one in five is about all that can be counted on in the undulating uplands bordering the foot-hills. Other things being equal, much of course depends upon the nature and depth of soil, the perfection and depth of tillage, and the practice of after-cultivation as against broadcasting. To guard against the effects of northers, and to prevent all avoidable evaporation of the precious moisture, it is the universal practice to roll the grain-fields as late as it can be done without injury to the growing grain. On sandy soils this can hardly be overdone; but on clay soils, should they be too wet when rolled, the effect will be the exact reverse of what is desired, and great injury often results.

It is the general estimate that whenever the rains have been adequate to make the moisture from above meet that rising from below a crop may be secured if the season be reasonably favorable; and since, other things being equal, the depth at which moisture is found at the end of the dry season will depend upon the amount of rainfall during the previous season, it makes a material difference whether a droughty season has been preceded by a wet one (as was the case in 1850–'51), or whether a scant rainfall preceded a deficient one. In the middle portion of the valley the summer's drought will reach on untilled soils to the depth of from 3 to 5 feet, according to the nature of the soil, and this mass has to be remoistened fully to that depth to give promise of success for field crops. When on the contrary, the surface has been kept in a state of good tilth during the summer ("summer fallowed"), the moisture will be found at a much less depth, the remoistening by the fall rains will be proportionally more rapid, and the chances for a crop will be materially increased from that cause alone.

In the extreme south of the San Joaquin valley the annual rainfall rarely moistens the soil to a greater depth than 2 or 3 feet, and in digging or boring wells in districts not irrigated the materials are found dry as dust to the depth of 40 feet and even more. At the first beginning of irrigation this entire mass has to be moistened before moisture will permanently remain within reach of the tap-roots of plants, and a very large amount of water is therefore at first required; but gradually the ground fills up, the water-table, and with it the plane of sensible moisture, rises more or less rapidly, the effect becoming perceptible at the distance of many miles in the porous soils of the plains, and ultimately the amount of water annually needed for irrigation becomes a small part of that needed during the first years.

a See Bulletin No. 31 of the University of California, February, 1878.

Irrigation in California.—Since the greater part of the state of California lies within the limits of the "arid" region as defined by Major Powell, (*a*) viz, a region having a rainfall of 20 inches and less, and within which successful agriculture is, as a rule, dependent upon irrigation, a discussion of the general aspects of this subject must of necessity precede any detailed presentation of the agricultural features and practice.

As has been before noted, the peculiar mode of distribution of the rainfall through the season—nearly all falling from November to May, and during the prevalence of a growing temperature for the hardier field crops, such as cereals and grasses—permits the full maturing of crops of rapid development before the setting in of the summer drought, at least in the more northern part of the region of scanty rainfall. In the warmer southern portions, where the evaporation is greater, a larger supply of water is necessary to insure crops; but, as the tables show, these portions have a scantier rainfall. Hence the necessity for irrigation becomes rapidly greater as we advance southward, and finally absolute, at least in the valleys. The lands lying near high ranges, and especially to the westward, are agriculturally favored by a greater precipitation, due to the condensation of moisture by such mountains, but the immediate coast, as well as the foot-hills of the Sierra, is less dependent upon irrigation than the plain of the great valley.

The commanding importance of the subject of irrigation in the state of California has repeatedly secured for it legislative attention, but no general measures toward ascertaining the resources of the state in lands and waters adapted to irrigation were taken prior to the year 1878, when an act was passed providing for the appointment of a state engineer, whose duties were defined to be, "under the direction of the governor, to investigate the problems of the irrigation of the plains, the condition and capacity of the great drainage lines of the state, and the improvement of the navigation of rivers." A succeeding portion of the act imposes the duty of inquiring into and reporting upon "the question of the flow of *débris* from the hydraulic mines into the streams, and the injury to agricultural lands by the flow of *débris* thereon".

Between 1878 and 1880 the work on both of these important branches of inquiry was actively prosecuted under the able direction of Mr. William Hammond Hall as state engineer, and in January, 1880, he submitted to the legislature, then in session, his first report, a highly important document. Most of the numerical data hereinafter given are taken from this report. Unfortunately, the agitation in regard to the mining *débris* question, which has increasingly irritated the public mind ever since the passage of the act providing for the building of dams to impound the tailings of the hydraulic mines, has overshadowed the irrigation problem for the past two years, and caused a curtailment of the appropriation available for that branch of the work.

The prominent point brought out in this litigation that has vexed the courts for several years past is the irrepressible conflict between the provisions of the common law on the subject of riparian rights and the requirements of agriculture in a region requiring irrigation. The declaration of the former that every riparian owner is entitled to the undiminished volume of the stream (intended evidently for the safeguarding of the interests of the uses of water-power) strikes at the very foundation of the use of water for irrigation purposes, and is thoroughly incompatible with such use, and, therefore, with the very existence of agriculture in the arid region; yet this law has been invoked again and again in California by riparian owners claiming the undiminished volume of the streams from those above them, while fully intending to use it freely on their own lands. The courts of the state have been embarrassed by the conflict of the acknowledged foundation of American civil law with the manifest equities of the cases before them. Decisions lately made, however, distinctly affirm that the common-law doctrine is not in this respect applicable in irrigation districts.

The control of water now used in irrigation ditches in California is almost altogether based upon the right of "prior appropriation", in pursuance of custom rather than law; a method not without its merits in respect to the promotion of irrigation enterprises, but liable to gross abuse in forestalling, since it places it within the power of the appropriator to carry the water to lands in which he is interested to the detriment even of riparian owners, who, under the common law, are entitled only to so much water as they require for household and stock, but not for irrigation. The forestalling, by means of the pre-emption, homestead, or timber privileges, of all the water-supply from springs available during the dry season has in California created a situation in which many such pre-emptors of 160 acres are, as a matter of fact, "lords of all they survey," since no one can occupy the adjacent lands without paying them tribute for water supply; and this is still more emphatically true of owners of large tracts, Spanish and Mexican grants, etc., which were usually selected originally because commanding water supply.

It is difficult to foresee how the many claims or rights acquired under this system in California can now be adjusted in accordance with the public interest without a severe wrenching of what it is usual to consider "vested rights"; but it will obviously become necessary to resort to the state's ultimate right of eminent domain in condemning the water available for irrigation to public use, under such regulations as will inure to the greatest good of the greatest number. In framing these measures it should not be forgotten that irrigated land is much more valuable and productive than that which is dependent upon the accidents of the seasons, not only because of its exemption from the risks and failures involved in the cultivation of unirrigated land even in the "humid" portions of the world, but also because of the important part taken by the solids dissolved or suspended in the irrigation water in

a See my article on the soils and agriculture of California, by E. W. Hilgard, in the report of the department for 1878, p. 478.

increasing and maintaining the fertility of the soil. The irrigator is exempted from the necessity of supplying manure to restore the soil ingredients withdrawn by his crops to an extent varying in different localities, but always taking the form of a very tangible balance in his favor, in some cases (as in that of the valley of the Nile for ages past) amounting to a complete relief from all consideration of the question of the maintenance of fertility, which is intruding itself more and more urgently into the calculations of American farmers and threateningly confronts every tiller of the soil in the Old World.

These considerations justify the adoption of a much smaller unit for the farm in irrigation districts, the more complete and systematic utilization of the soil's powers enabling a smaller area to subserve the needs of a family. The unit of 80 acres, as suggested by Major Powell, instead of the usual 160, is certainly amply large in soils of any reasonably adequate native fertility; for in the irrigated colonies of southern California 20-acre lots are the usual homestead units on which industrious families make a fair living.

In these points of view may also be found a partial answer to the question frequently asked, what inducement is there for the settler to occupy the regions, laboring, apparently, under so many natural disadvantages, when so much fertile land remains unoccupied in more favored regions? From an abstract point of view the question seems difficult to answer, but concretely the explanation lies in the fact that human nature *will* take risks where there is a reasonable chance of success, as is the case in humid climates; whereas in the arid regions, success being impossible without irrigation, but becoming a certainty with it, farming becomes a much more safe, satisfactory, and paying occupation. If, on the other hand, we inquire why it is that the abundant water supply of the humid regions is not utilized with the same view of reducing the success of crops to a certainty, instead of risking the disastrous failures that afflict them from time to time in the occurrence of droughts, we can but point to that same principle of human nature which renders gambling so dangerously attractive and drives the "prospector" to continue in the search for new mines, rather than to settle down to the working of those he has already discovered.

Aside, however, from these considerations, the treelessness of irrigation countries is in itself not a slight advantage to the settler of small means, since it relieves him from the necessity of incurring the great expense and delay of "making a clearing"; an operation often involving in humid climates an expenditure altogether out of proportion with the productive value of the land. In the great valley of California, as in the prairies of the West, the plow can be put into the land without any preliminaries; but there is no heavy sod, necessitating the use of correspondingly heavy draft, the first plowing being nearly as easy as the later ones.

In climates having a long growing season, so far as temperature is concerned, the effects of irrigation on actual production are almost startling. Thus, in the southern part of California, as well as in western Arizona, crops may be started at whatever season suits the convenience of the grower, except two months in the year; and this holds true for market gardens as far north as San Francisco, where vegetables of nearly all kinds can be had in the market almost throughout the year. In Tulare and Kern counties five cuts of alfalfa have been taken off the same field in a single season and ten tons of its hay made; of sorghum, Egyptian corn, and pearl millet, when cut for forage, with irrigation, three heavy cuts per acre have been made—an enormous yield, which, of course, could be maintained only on a very strong soil, or, later, by the aid of manure. But irrigation enables the farmer to impart to the penny a nimbleness unheard of in regions dependent upon the seasons alone. The investment of a certain amount of money in land and manure can be "turned over" twice in the season, or even oftener in a region of long summers. There is no reason why the same could not be done in the southern states; but, as a matter of fact, it is done only where irrigation is compulsory.

The main irrigable area in the state is the great interior valley, embracing altogether about 30,000 square miles. Of this area about 11,300 square miles belong to the San Joaquin valley from the Cosumnes river to the Tejon mountains, a maximum length of 260 miles by from 30 to 70 miles in width. It is here, as well as in the southern region (Los Angeles, San Bernardino, and San Diego), that the irrigation question assumes the character of a vital problem, a *conditio sine qua non.* In the Sacramento valley irrigation is but little resorted to on the east side of the river, where, on the contrary, the mining *débris* problem agitates the public mind, and mining ditches furnish the supply of irrigation water chiefly to the foot-hill lands and mountain plateaus; while on the west side, in the counties of Yolo, Solano, and Colusa, irrigation is again prominent, though not so vital as in the San Joaquin valley, on account of the greater annual rainfall. Irrigation in the San Joaquin valley is thus far practically confined to that portion lying east of the trough and traversed by the rivers issuing from the Sierra Nevada. The total of the dry plain lands of this "east side" embraces an area of 7,687 square miles, of which about 69 per cent. may be assumed to be irrigable from the current water-supply of the streams. Since the trough of the valley lies much nearer the Coast range, in fact, touches the foot-hills at Buena Vista slough, in Kern county, the area of the "west side" is very much smaller, viz, about 2,689 square miles. As Mr. Hall says:

> All south of Tulare lake and a large portion north of the lake, on the west side, may be classed as non-irrigable land, not only on account of the absence of a sufficient water-supply, but by reason of the general unfitness of the soil for cultivation by irrigation. The sources of supply for irrigation are Tulare lake, the San Joaquin river, and the small streams of the Coast range.

According to the analysis of its waters, Tulare lake is altogether unfit, either as a source or even as a reservoir of irrigation waters, on account of its alkalinity, as stated more in detail further on. The small intermittent creeks flowing from the Coast range are but little to be relied upon in this connection, the more as the porosity of the formations in that region renders storage very precarious. Supposing King's and the San Joaquin river to be the only available sources of supply, the irrigable lands of the west side would, according to Mr. Hall, be about 718 square miles, or 460,000 acres, making the grand total of lands irrigable from sources adjacent to the plain of the San Joaquin valley (exclusive of storage in higher reservoirs) about 6,000 square miles, or 3,840,000 acres. Of this vast area of highly productive soils only about 188,000 acres, or about 5 per cent., are estimated as being at present under irrigation.

Artesian water is to a limited extent already used for irrigation in the San Joaquin valley. In a few cases saline and alkaline waters have been obtained from the wells, but a considerable number have water that is no more objectionable than that of Kern river at least. Of late such wells, yielding abundant streams, have been obtained in Tulare county, in a region much troubled with alkali, which they will help to subdue. The possibilities of the valley in this respect have hardly yet been approximately ascertained, and it is very important they should be.

In the Sacramento valley the lands irrigated from Cache creek aggregate about 13,400 acres. There are no data for estimating the other irrigated lands of the plain, but the amount of irrigated land in the foot-hills of the Sierra (chiefly opposite the central portion of the great valley) may be taken at about 9,000 acres.

With the exception of Cache and Putah creeks, on the west side of the Sacramento valley, no important amount of irrigation water can be derived from the Coast range except through winter storage, which has not thus far been practiced. To the seaward of the Coast range small tracts of irrigated land are found from San Francisco southward, but they form the exception northward of Santa Barbara. In the Salinas valley it is not convenient, because of the small volume of the river and the lack of tributaries, and fair crops are made without it. Farther south it is more or less practiced in many of the seaward valleys, very generally so in the valley of Santa Barbara, and thence southward increasingly, until in the Los Angeles region the maximum proportion of irrigated lands is reached, the total in the counties of Los Angeles and San Bernardino reaching nearly 85,000 acres, and but little land being cultivable without it.

The amount of water available for irrigation can be very largely increased by winter storage in mountain reservoirs, storage in the hot lowlands, on account of evaporation, being wasteful. This, however, requires large capital and co-operative action, and will hardly be resorted to for some time to come, or until the water obtainable by the diversion of streams is exhausted.

The *practice of irrigation* by flooding is by far the most prevalent in California, but to a limited extent, in districts with sandy soils, lateral seepage from ditches is alone relied upon; and still more limited is the practice of sub-irrigation by means of cement pipe with outlets, which has come into use mainly for orchards and vineyards, especially where the supply of water is very limited, and can thus be made to do a much higher "duty" than by any other method. Its expense (ranging from $30 to $50 per acre) limits its application to crops of high value.

The duty of water under the ordinary systems varies greatly, not only according to the nature of the soil and underlying materials, but also with regard to the time that has elapsed since the beginning of irrigation in each district. This is especially apparent in the San Joaquin valley, whose porous soils are underlaid by sandy and gravelly beds easily permeable by water, and which in their natural state show no trace of moisture sometimes to the depth of 40 feet or more. At first all this dry mass requires to be saturated, and an enormous consumption of water occurs, amounting to many times the quantity that after a few years will be found amply sufficient to maintain vegetable growth. The water, of course, not only sinks vertically, but also drains sideways, and moisture is gradually found at lessening depths and at increasing distances from the ditch and irrigated land, thus benefiting parties altogether outside of the area intended. Again, irrigators are generally inclined to use water with unnecessary and even injurious liberality at first, until experience shows them that, especially in the case of fruit crops, a certain moderate allowance only insures the best result. "Over-irrigation" is the result of the natural instinct to supplement amply the deficiencies left by nature, but its disadvantages are coming to be more and more understood.

It is hardly possible to give an average of the duty of water in the irrigation districts of the state, but it may be broadly said that it varies from as little as 50 acres per second-foot in the newly colonized districts of the San Joaquin valley to over 500 acres in the colonies of the southern or Los Angeles region.

Agricultural regions of California.—In most of the states embraced within the present series of reports the agricultural divisions are naturally based upon differences of soil and surface conformation arising from diversity of the underlying geological formations. In California the natural and generally recognized subdivisions are essentially dependent upon climatic differences, arising in the main from the topographical features, in which the several geological formations, as such, play only a subordinate part. From this point of view the several portions of the state may be conveniently considered under the following heads, transition zones of greater or less extent intervening, of course, between the several areas here defined:

1. *Region of the great valley*, with high summer temperature, intensely dry atmosphere, and no summer fogs. It is subdivided into:

A. The *Sacramento valley*, with from 20 to 40 inches rainfall; little irrigation needed. There is commonly a light snowfall in winter, the temperature falling as low as 26°, and frost temperatures at night for several months. The prevalent winds "up valley" are from somewhat west of south.

B. The *San Joaquin valley*, with from 4 to 16 inches of rainfall. Snow is rarely seen in the valley. The summer temperature is higher than in the Sacramento valley, but the nights are usually cool, especially in the upper part. Irrigation is needed for the safety of all field crops, and more or less for all others. The prevalent winds are "up valley", *i. e.*, from somewhat west of north.

2. *Foot-hill region of the Sierra Nevada and of the northern coast range* up to 2,500 feet elevation. The rainfall is greater than at corresponding points in the valley, increasing at the rate of one inch for from 100 to 150 feet ascent. The summer temperature is about the same as in the valley; the winters are somewhat colder, yet in sheltered locations frosts are very light.

3. *Semi-tropical or southern region.*—This region consists of the counties of Los Angeles, San Diego, and part of San Bernardino. The rainfall is from 13.6 to 9 inches, and irrigation is indispensable for almost all cultures. Frosts are rare, permitting the culture of semi-tropical fruits in the open air despite an occasional cutting-back in severe seasons. The prevailing summer winds are southwest, and fogs are rare.

4. *Arid plateau climate, or Southern desert region*, with from 8 to 4 inches rainfall and less; very variable, and some years almost none. This region embraces the Mojave and Colorado deserts, and is largely an irreclaimable sand and alkali desert, but has some fertile valleys, yielding well when irrigated, such as Owen's valley, Inyo county.

5. *The coast region*, having cool summers and warm winters, the ground rarely freezing, even superficially, save in the most northerly portions. Cool and moist westerly winds are predominant. This region is subdivided as follows:

A. *Region north of the bay country*, embracing—

(*a.*) Region near cape Mendocino and north of it, with from 32 to 80 inches of rainfall, northwesterly winds, occasional summer showers and thunder-storms, and snow often lying several days in the valleys. This is a transition to the Oregon climate.

(*b.*) Region south of cape Mendocino to the bay country, with from 20 to 32 inches of rainfall.

B. *Region of San Francisco bay* southward to Santa Cruz, with from 20 to 25 inches of rainfall and steady westerly summer winds and fogs; practically no summer showers, and no large-scale irrigation. Snow reaches the valleys only exceptionally, but light frosts occur for several weeks in winter as a rule.

C. *Region south of the bay country* from Monterey to Los Angeles, with from 9 to 16 inches of rainfall, and summer winds somewhat south of west, carrying fewer fogs than in the San Francisco region. Irrigation ordinarily is needed for field crops. Snow occurs only on the mountains, and frosts are rare.

6. *Mountain region of the Sierra Nevada and northern California.*—Summer and winter is well defined, and snow lies during several months in the higher regions to great depths, and with very severe cold. The rainfall ranges from 20 inches at the south to 100 inches at the north.

A. *Lava-bed region* of northeastern California, with from 20 to 22 inches of rainfall.

B. *Arid region* of the eastern slope of the Sierra.

C. *High Sierra*, a region of fir and pine forests and pasturage.

THE GREAT VALLEY OF CALIFORNIA.

The great valley of California, embracing a large proportion (one-third) of the agricultural lands of the state, is included between the foot-hills of the Sierra Nevada on the east and the Coast range on the west, the general direction of its axis being nearly northwest and southeast. Its length from the Tejon mountains, on the south, to Red Bluff, on the north, where the valley proper terminates, is about 400 miles, while its width varies from over 60 to somewhat less than 40 miles. Its total area is about 17,200 square miles.

Since the drainage is toward a point lying about three-fifths of its length from the southern end, where the San Joaquin and Sacramento rivers unite at the head of Suisun bay, the general slope of the surface is of course in that direction lengthwise. A cross-section will, in general, show the great drainage trough to lie westward of the axis (especially in the San Joaquin valley), with a gentle talus-like slope toward it from the foot-hills of the Sierra, while the Coast range mostly falls off rather abruptly into the valley, or into the trough itself. This is the natural result of the washing down of material from the long and elevated western slope of the Sierra, which also at present furnishes practically all the drainage slope from which the waters of the valley are derived, while the drainage from the Coast range is insignificant. These talus lands constitute an upland plain—for such it appears to the eye—into which the rivers emerging from the cañons of the foot-hills have cut valleys varying in depth from 40 to 140 feet at the eastern margin of the valley, but becoming shallower as the trough of the main rivers is approached. These lateral valleys are mostly quite narrow, varying from less than a quarter of a mile to (rarely) as much as one mile and more. They are usually timbered, and these timber belts form landmarks in the otherwise commonly treeless plain that are mostly visible from one tributary to another. In the San Joaquin division the lateral valleys are mostly bordered by abrupt bluffs; in the Sacramento valley rolling slopes come down to the bottoms proper.

In both valleys the main channel is, for a part of its course, bordered by fresh-water marshes, or "tule lands". From these the land rises gradually to the eastward to the level of the "plains", which on a large scale have a level or gently rolling surface, while on the small scale they are to a considerable extent dotted with the singular rounded hillocks, popularly known as "hog-wallows", from 10 to 30 feet in diameter and from 1 to 2 feet high, which are evidently the result of erosion, but precisely under what conditions it is difficult to explain. These hillocks are usually most abundant near the foot-hills, with long scallops toward the valley, and the tracts seem to diminish in width toward the axial "trough", which they seldom reach, but they do not always bear any definite relation to the present streams. They occur on all kinds of soil, and even on the rolling foot-hill lands themselves, constituting an obstacle to easy cultivation that it is sometimes quite costly to remove; the more as their material is usually somewhat more compact than that of the intervening lower soil, and their leveling involves the baring of the subsoil. In some cases they are so thickly set, abrupt, and resistant as to render the land valueless for ordinary cultivation. They are almost always present on strongly alkaline soils, and one may often see them bearing good grain crops, while on the lower portions of the land the soil is whitened with alkali and the grain is dying. Oddly enough, in other cases, in consequence of differences in the capillary power of the soil in the two locations, precisely the reverse is seen. "Hog-wallow land" does not, therefore, imply any definite character of soil in general, although locally the character is often an exceedingly definite and distinct one.

The flood plains or tule lands of the streams are commonly bordered by more or less interrupted belts of land impregnated with an unusual amount of soluble salts or "alkali", which, during the dry season, bloom out on the surface and often interfere more or less with successful cultivation unless special precautions are taken to counteract their influence. Alkali is also sometimes found on the higher lands, especially in the San Joaquin valley, where the light rainfall is favorable to its accumulation. A discussion of this subject is given in the appendix to the regional descriptions.

The larger streams of the great valley have two periods of flood: one, caused directly by the winter rains, usually in the latter part of December and in January; the other, caused by the melting of the snows in the Sierra, affects only the rivers heading there, but is the most important from the irrigator's point of view, since it occurs at the time when water is most needed, in March and April, its duration and degree varying greatly in different seasons. The short streams heading in the foot-hills are, of course, only of limited importance to the irrigator so long as their water is not stored in winter.

The marsh or tule lands of both valleys will be considered jointly after the description of the higher lands.

THE SACRAMENTO VALLEY.

The length of the Sacramento valley from its extreme head, a few miles above Red Bluff, Tehama county, to the Calaveras river, in San Joaquin county, is about 160 miles. From a width of about 7 miles opposite Red Bluff the valley widens to about 15 miles near the Tehama line, 3 miles from the head, and then suddenly expands westward, assuming its average width of about 40 miles or a little over. Northwest of Woodland, Yolo county, it is narrowed, by a promontory of red foot-hill lands projecting into the plain from the Coast range, to about 33 miles, but below this rapidly widens again to its maximum width of 60 miles opposite Suisun bay. The area is about 6,200 square miles.

In the upper, narrow portion of the valley the streams enter at short intervals and squarely from either side, those from the Sierra especially emerging from deep, narrow, and rugged cañons cut into the lava-bed formation, and flowing for some miles in the belt of stony, treeless country at the foot before reaching the fertile alluvial plain of the river. The latter is quite narrow and distinctly defined from the red and usually more or less gravelly soil of the higher plain, which is treeless almost throughout, and is a heavy grain-growing region.

Southward, in Colusa and Butte counties, the foot-hills on either side are less abrupt, and a belt of undulating or rolling land of varying width, with red or yellow loam soils, borders the eastern side of the valley, sometimes merging gradually into the lands of the valley proper, and then again forming rather an abrupt terrace on the edge of the alluvial trough. Usually there intervenes between the latter and the red border lands a belt of adobe lands of varying width, which on the eastern side are mostly black (when wet), underlaid by a whitish calcareous hard-pan at a depth varying from 1 to 4 feet. In most cases these adobe lands are very productive and not very heavy in tillage. On the west side, in Colusa county, the adobe belt is even wider than on the east, but the soil is mostly of a gray tint, very refractory in tillage, and largely impregnated with alkali salts; hence the lands chiefly cultivated are those of the river trough (a fine silt soil of great productiveness), the tracts of partially alluvial soil deposited by the intermittent tributaries from the Coast range, and the red gravelly lands bordering the valley at its foot.

The drainage in this portion of the valley is of an exceptional character. On the west side the Coast range streams reach the great trough only in time of flood or of heavy rains, but during the greater part of the year they lose themselves about half way. On the east side the Sacramento receives no tributaries, the Sierra drainage being here received by Feather river, which emerges into the plain near Oroville, and thence for more than 50 miles in a direct line pursues an independent course in the valley, gradually converging toward the Sacramento river, with which it finally unites only about 18 miles from Sacramento city. The valley is thus on the east side divided between these two rivers, which are separated by a divide that rises rather abruptly from the trough of Feather river, then slopes off gently toward the Sacramento river, as does the plain on the east to the Feather itself from the base of the foot-hills.

The cause of this deflection of Feather river from its direct course to the central trough is manifestly the short but rugged volcanic mountain mass of the "Marysville Buttes", which here appears in mid-valley, forming a prominent landmark in the plain. The buttes, with their foot-hills, occupy an area of about 4 by 12 miles, and the bare, disrupted rocks and precipices of the central mass contrast oddly with the fertile plain around; the foot-hills, however, embrace some good grazing land. Immediately at their base the soil is gravelly, but soon shades off into heavy black adobe. On the south side this adobe tract is traversed by Butte slough, through which, in time of flood, a part of the waters of Feather river find an early outlet into the Sacramento.

Originally the soils of the immediate valleys of the Feather and Yuba rivers did not differ greatly from those of the Sacramento near and above Colusa. At the present time much of the valley lands of both streams has been overrun with the *débris* of the hydraulic mines, and their channels, to a great extent, meander in flood-plains formed by alternating deposits of coarse gravel, sand, and the finer deposit now too well and widely known under the designation of "slickens". The destruction of farming lands by this agency has already reached enormous proportions, and the filling up of the river beds by the continued influx of the overloaded waters causes these deposits to spread farther and farther every year, resulting in immense damage, not only from the flood itself, but also from the repeated deposits of the sediment, which, though an occasional dressing with it might be an improvement to the adobe soils of the central valley, is far from forming a desirable soil in itself. (*a*) The evil affects, of course, not only all the country adjacent to the Feather, Yuba, and their tributaries, but also the entire valley below the junction with the Sacramento. Hence, with a comparatively abundant rainfall and only a limited need for irrigation, the prominent topic in the Feather and lower Sacramento valley is the "*débris* question", the final adjustment of which between the conflicting interests of the farmers and those of the hydraulic miners has hardly yet approached the phase of a definite common basis. The peaceful town of Marysville, once known as "the city of the plains", now frowns upon the visitor from behind levees of such height and massive strength that he instinctively looks for the cannon that is to defend a beleaguered city. Yet, even as they are, these levees need the constant watchfulness of the inhabitants and an annual heightening and strengthening against the annually increasing floods. Outside the walls, where there was once a fertile bottom, traversed by a quick and clear stream, stretches a sandy and gravelly waste, through which the waters of the Yuba meander in sluggish and dirty loneliness. Nothing can be more eloquent of the pressing need of a final disposal of this evil, the magnitude of which can hardly be realized by those who have not seen with their own eyes.

Below the Yuba again, and down to the American river, but few of the foot-hill streams reach the main Feather river, save in flood time. Their waters are partially utilized for irrigation near the foot-hills, but, on the whole, the grain crops for which this region is noted succeed well without its aid. An analysis of the loam soil of the neighborhood of Wheatland, Yuba county, from the rolling upland belt, in which the valleys of the streams are but slightly sunk, is given on page 22.

A broad tract of alluvial land, of high productiveness but liable to overflow, lies in the fork of the Sacramento and the American rivers; it is largely protected by levees along the banks of the rivers.

Southward of the American river, and across the Cosumnes and the Mokelumne to the Calaveras river, extends a plain, broken only by occasional swales of reddish soil running in from the foot-hills. This is one of the most productive and thickly-settled portions of the entire valley, the soil being mostly a dun-colored loam, varying in its lightness, but throughout easily tilled. Besides grain, which occupies the greatest breadth of land, vineyards and orchards are conspicuous in its landscape, which is here and there dotted with oaks, while the horizon is bounded by the timber belts along the water-courses. Irrigation increases as we advance southward, but is not usually applied to the larger field cultures, although this might beneficially be done to the full extent of the capacity of its streams, as it will undoubtedly be whenever the now predominant grain production shall be superseded by a more varied system of culture. The direct distance from the foot-hills to the mouth of the Mokelumne is about 38 miles, and for the greater portion of this distance its valley is so depressed below the general level of the plain that, for irrigation purposes, its waters must be tapped within the foot-hills. The distance between bluffs is from one-half mile to one mile, and the channel is bordered by rich alluvial bottom lands lying above ordinary floods. A short distance below Woodbridge the river enters the great tule region.

Opposite the region just considered, across the broad tule belt encompassing the junction of the two rivers, lie the rich alluvial plains of Yolo and Solano counties, the soils of which are of pre-eminent fertility, being a mixture of the finest natural sediments of the Sacramento river with those carried by the streams heading in the volcanic portion of the Coast range (of which Cache and Putah creeks are the chief), experience in this respect being confirmed by the analysis given further on (see 110 in table). The plain is scarcely broken by the slight undulations or swales coming down from the foot-hills; but the region is thickly settled, and is largely occupied by orchards and vineyards.

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a See analyses on page 22.

Irrigation is not general, chiefly on account of the limited water supply, which is dependent mainly upon the limited volume carried by Cache and Putah creeks, but partly and increasingly upon shallow wells sunk into the water-bearing gravel which underlies the region. This fact and the great depth of soil renders grain crops measurably independent of irrigation.

Cache and Putah creeks, not being supplied by winter snows or forest-clad ranges, are intermittent streams, carrying in the winter season formidable floods, which then partly find their way across the country to the trough of the Sacramento, while they become insignificant during the dry season, or even between the rains which drain rapidly from the steep slopes of the Coast range.

Nearly one-half of the drainage of Cache creek is received into Clear lake, which thus to some extent serves as a regulator of its flow. From the lake the creek passes through a cañon about 30 miles in length, receiving two large tributaries from the north before it enters the head of Capay valley. The latter is about 18 miles long and 1 or 2 miles wide, and has a considerable area of irrigable though somewhat heavy land.

On entering upon the Sacramento plains the creek widens out into a channel from 500 to 1,000 feet in width with low banks and decreased grade, and before reaching the town of Cacheville is confined between vertical banks from 20 to 25 feet high and from 100 to 150 feet apart, which condition it maintains for several miles; but on approaching the lowland of the Yolo basin the banks drop away, and the stream is free to spread out in a broad delta, seeking the lowest part of the basin, and emptying into the Sacramento river through Cache slough.

Soils of the Sacramento valley.

The soils of the Sacramento valley are as yet but very inadequately represented by the subjoined analyses, the material on hand being too limited to allow of selecting representative samples advisedly. Nos. 563 and 110 are probably of wide applicability, and Nos. 517 and 561, taken together, may also probably be taken as fairly representative of the loam of the east side of the valley. Of the true "adobe" of the valley no analyses have thus far been made.

No. 563. *Sediment soil* from near the banks of the Sacramento river, on the Rancho Chico, General Bidwell's land, Butte county. A gray or dun powdery loam, with but little coarse sand, very easily tilled, and the same to a depth of several feet; is well timbered with white oak (*Q. lobata*), ash, and sycamore, with abundance of grape-vines, and is very productive in cultivation. Depth taken, 12 inches.

No. 561. *Dark "adobe" loam soil* from the Rancho Chico, about a mile east from the spot where No. 563 was taken. Dark tinted and moderately heavy, so that after drying it can still be crushed between the fingers; taken to the depth of 12 inches, becoming paler colored below that depth; originally treeless, bearing a growth of sunflowers and alfilerilla. This soil is not as regularly or as highly productive as the river land.

No. 517. *Reddish soil* from near Bigg's Station, Butte county, a clay loam, brownish dun in color when dry and brownish black when wet. The dry lumps are hard to crush between the fingers, but soften quickly on contact with water. This soil occupies a level belt, lightly timbered with oaks, to the eastward of the adobe belt of this region. Between the two there usually intervenes a streak of whitish soil, from which there is a gradual transition to the true adobe. Depth taken, 12 inches.

No. 656. "*Slickens*," or fine mining *débris* deposit, from Yuba river, Yuba county, sent by the secretary of the "*débris* committee" of the city of San Francisco. Light yellowish gray, partly in powder, partly in chalky lumps, easily crushed, very light, and scarcely palpable, emitting a strong clay odor when breathed upon or when wet.

No. 1004. "*Slickens*" *sediment* from Alger's bend, Feather river, Butte county, furnished by Mr. Julian Le Conte, of the United States river and harbor survey. A compact, yellowish-brown lump, somewhat heavier than No. 556, which can be crushed between the fingers with little difficulty to an altogether impalpable powder, and emits a strong clay odor when breathed upon or dampened. The deposit is stated to have been from 6 to 8 feet in thickness in the bed of the river, which upon drying forms wide gaping sun-cracks, allowing a man to walk between the blocks on a base of sand. When deposited it must have been almost in a gelatinous condition.

No. 10. *Sediment soil* from the farm of Mr. Daniel Flint, on the Sacramento river, a few miles below Sacramento city, Sacramento county, deposited during high water, and said to exert a remarkable effect in increasing the productiveness of the land, especially clay land, upon which it may be brought. It is a light, buff-colored silt, almost impalpable when rubbed between the fingers, and without sand or gravel. Depth taken, 12 inches.

No. 110. *Soil of Putah valley*, near Dixon, Solano county, sent by J. M. Dudley, from the "middle land" of the plain, on the slopes of the swales, about 3 feet above the lowest land. Depth taken, 12 inches.

No. 499. *Red upland loam soil* from near Wheatland, Yuba county. A stiffish, glaringly orange-red loam, forming the soil of the undulating uplands stretching from the foot-hills several miles into the valley, and but little above the general level of the latter; it tills easily when taken in the right moisture condition, but plows very cloddy when either too wet or too dry. This soil is chiefly given to pasture and wheat growing, and yields from fifteen to twenty and sometimes twenty-five bushels of fall or winter-sown grain in good years, and in poor ones from eleven to thirteen bushels per acre, but never altogether fails. It responds very kindly to summer fallowing, and in its natural condition has almost only herbaceous vegetation, with some scattered poison-oak bushes.

Soils of the Sacramento valley region.

	BUTTE COUNTY.			YUBA COUNTY.	BUTTE COUNTY.	SACRAMENTO COUNTY.	SOLANO COUNTY.	YUBA COUNTY.
	Sacramento river alluvium, Rancho Chico, S. 27, T. 22, R. 1 W.	Black-loam soil, Rancho Chico.	Brownish-loam soil, Bigg's Station.	"Slickens" from Yuba river.	"Slickens" sediment, Alger's bend, Feather river.	Sediment soil, Sacramento river.	Putah valley soil, middle land.	Red-loam soil, Wheatland.*
	No. 563.	No. 561.	No. 517.	No. 656.	No. 1004.	No. 10.	No. 110.	No. 499.
Insoluble matter	70.764 } 73.444	59.144 } 62.304	63.268 } 68.018	72.169 } 75.240	61.029 } 69.062	55.283 } 69.223	67.334 } 71.005	78.789 } 82.592
Soluble silica	2.680	3.160	4.750	3.071	8.033	13.940	3.671	3.803
Potash	0.652	0.305	0.453	0.267	0.300	0.353	0.929	0.240
Soda	0.077	0.221	0.113	0.025	0.124	0.065	0.124	0.035
Lime	1.444	2.909	1.460	0.794	0.521	0.901	0.770	1.021
Magnesia	2.277	1.042	2.174	0.866	0.768	1.249	2.285	0.471
Brown oxide of manganese	0.015	0.025	0.105	0.025	0.089	0.111	0.106	0.018
Peroxide of iron	5.804	9.342	8.585	6.582	6.586	6.316	8.011	5.811
Alumina	10.397	13.038	12.045	10.390	14.229	15.251	9.159	6.283
Phosphoric acid	0.087	0.095	0.064	0.076	0.078	0.250	0.111	0.043
Sulphuric acid	0.030	0.068	0.047	0.134	0.067	0.097	0.120	0.019
Water and organic matter	5.351	10.149	6.701	5.716	8.024	6.751	7.115	3.644
Total	99.578	99.498	99.765	100.115	99.848	100.567	99.735	100.186
Humus	0.749	....	1.184	....	....	....	1.709	0.466
Available inorganic	0.255	....	0.464	....	....	....	0.562	0.336
Hygroscopic moisture	6.84	13.980	8.29	....	10.09	....	10.315	4.81
absorbed at	11.5 C.°	13 C.°	13 C.°	....	15 C.°	....	15 C.°	....

*No. 499 is properly a foot-hills soil, lying in the edge of the plain, and is introduced here for comparison with the valley soils proper.

The common characteristic of all these soils is an adequate and, in some cases, a generous supply of lime, which insures the availability of the plant-food they contain, greatly enhances their power of resisting drought and of forming and retaining humus, and renders them easily tillable, notwithstanding the large amount of clay they contain. This feature, as will be seen hereafter, characterizes to a greater or less extent most of the soils of the great valley from Redding to Bakersfield, and it is with constant reference to it that their agricultural qualities must be considered.

Passing to the other primarily important ingredients of plant-food, we find that in the alluvial soils proper—as in that from Dixon and from the Sacramento near Chico—the amount of potash is large, in the former case even very large. Away from the river this ingredient diminishes in the case of the Rancho Chico to one-half of what it was near the river, the deficiency being partly offset by a very large supply of lime in No. 561, which manifests itself in its dark tint. In the soil from Bigg's Station, the tint of which indicates a partial derivation from the red materials of the foot-hills, the potash supply is more ample.

In none of these soils, however, is the supply of phosphates a large one. In that from Bigg's Station, but for the presence of a liberal amount of lime, it would be accounted deficient. Whenever their production shall have been materially diminished by exhaustive cultivation the use of phosphate fertilizers will evidently be the first thing needful to restore productiveness.

Nos. 656 and 1004 may be considered as fairly representative of the composition of the finest material, or "slickens", brought down from the hydraulic mines by the Feather and the Yuba rivers and deposited in their back or slack waters. A comparison of their composition with that of the above soils shows that they do not differ very widely in their mineral ingredients, as might be foreseen from the community of their origin. Their potash percentage is low, yet not lower than that of some good soils. The lime percentage, while lower than in the Sacramento alluvium, is reasonably high, and the supply of phosphoric acid, while not large, is only a little below the average of the soils analyzed. It may be expected, therefore, that whenever these "slickens" soils shall have been subjected for an adequate length of time to the same agencies that have been active in the natural alluvial soils they may become equally productive. As they are, however, they lack a high essential of all agriculturally valuable soils, viz, the humus or vegetable mold, whose physical as well as chemical action is so important to the welfare of plants that popular belief has long ascribed to it a controlling influence on fertility; and although we now know that humus is but one of the many factors that contribute to the productiveness of soils, we also know that, practically, its deficiency or its absence is an effectual bar to profitable culture. Under the climatic conditions of the Sacramento valley it will take many years to remove this disability in the natural course of things. The process may be hastened by the operation of green-manuring, provided green crops can be grown on the material; and this will, in general, be the most important step toward the reclamation of tracts covered by "slickens".

It is hardly necessary to advert to the fact that the material of the *débris* brought down from different channels and at different times may vary indefinitely, from cobble-stones, through gravel and sand, to the finest matter, graphically designated as "slickens", and, according to the sources from which the latter come, the chemical composition will also vary locally. Moreover, when a coat of moderately sandy material is deposited on adobe land, the intermixture of the two by the plow may oftentimes result in a material improvement in consequence of the removal of the extreme mechanical intractableness of the clay land. In other cases a local deposit may be exceptionally rich in some important ingredient, and may thus serve directly as a fertilizer when applied to cultivated land. Analysis No. 10 shows a case in point, in which a deposit on the banks of the Sacramento river is so rich in phosphoric acid as to be available as a fertilizer on the adjacent alluvial lands. Some of the effects observed may also, it is true, be due to the improvement of the mechanical condition.

It cannot, therefore, be surprising that the testimony as to the local effects of "slickens" on land overrun by it should vary considerably, according to the circumstances of the case. Cobble-stones and gravel will in every case be considered an unmitigated detriment. A moderate coat of sand spread on an adobe tract may be welcomed at first, but its repetition will naturally be objected to, and a deposit of any considerable thickness will effectually spoil the land forever. So also a moderate coat of "slickens" will, on the low and heavy lands on which it is most widely deposited, be at first a benefit, as it will improve the tilling qualities of the land, and, finding a sufficiency of humus in the soil, its fineness will cause it to be promptly acted upon and utilized as a source of plant-food. But whenever the deposit is repeated, the advantage diminishes, and finally changes to a very positive detriment so soon as the "slickens" becomes the predominant ingredient of the cultivated soil, while a thick deposit coming at once will, for the time being, and usually for many years to come, deprive the farmer of the profitable use of his land, albeit it may become profitable to his children or his grandchildren.

Such I consider to be the impartial view of the "slickens" question, independently of the obstruction of channels and consequent overflows, the consideration of which lies outside of the province of this report.

THE SAN JOAQUIN VALLEY.

The division of the great valley traversed by the San Joaquin and its tributaries constitutes about three-fifths of the whole, its area from the southern end to the Calaveras river, a distance of about 240 miles, being about 11,000 square miles. Its prominent topographical feature, as against the Sacramento valley, is the lake basin formed in its southern half by a low water-divide which traverses the valley in the southern part of Fresno county, by which the waters of King's river are thrown southward into Tulare lake. Northward of this divide the San Joaquin river enters the valley, and, traversing it, turns northward on reaching the trough, receiving thereafter directly the entire drainage of the Sierra. The valley is thus subdivided into the southern or *Tulare basin* and the *San Joaquin basin* proper.

At present this cross ridge is intersected near its western end by Cole slough and other channels, through which the surplus waters of Tulare lake or King's river can find their way into the San Joaquin. Previous to the formation of this outlet the entire upper valley was evidently for some time a shallow lake, of which Kern, Buena Vista, and Tulare lakes, with their bordering tule swamps, are the remnants. The main tributaries of this basin, heading in the Sierra itself, are the Kern, Kaweah, and King's rivers, which carry running water throughout the year. Besides these there are numerous water-courses, of more or less intermittent character, heading in the foot-hills and reaching the main trough only in time of flood or not at all, such as Posey, White, Tule, and Deer creeks, which can therefore be relied on for irrigation to a limited extent only. These water-courses are bordered by moist lands, which do not require as much water as the higher plains.

The streams of the Tulare basin enter the valley from the Sierra cañons in remarkably shallow channels, but then cut deeper ways into the plains proper, again approaching the general surface as they near the trough, which lies about two-thirds of the way to the Coast range. The streams descending from the latter are of the most intermittent character, the slopes of the range being steep and bare of forest; so that the land drains the more rapidly, as it is mostly very sandy. Hence the Coast range streams mostly lose themselves before reaching the trough, and are in any case available for irrigation only locally and to a limited extent unless stored. This character of the Coast range drainage is also the same northward in the San Joaquin basin. The streams flowing from the Sierra, on the contrary, there lie in deeply-cut channels for many miles out from the mountains, and do not approach the level of the plain until shortly before reaching the trough, when they turn northward.

The Tulare basin.

The Tulare basin is terminated on the south by the amphitheater of the Tejon and Tehachapi mountains, which rise from the valley with rather a gentle slope of good grazing lands, but are destitute of timber, as seen from the valley. Conforming in shape to that of the base of the mountains, but separated from the latter by a slightly sloping plain from 8 to 10 miles wide, lies the V-shaped trough of lowland in which Kern and Buena Vista lakes form sheets of water, at present rapidly decreasing, disconnected from one another by the lowering of the water-level by evaporation. From the same cause these waters are very sensibly alkaline, and, of course, increasingly so as the evaporation progresses, the same characteristic being imparted to the shore-lands left by the receding waters. At the western end of the trough, Buena Vista slough connects (or connected) the lake of that name with the southern end of Tulare lake. This slough at one point touches the base of a projecting spur of the Coast range, but below or northward of that point it is bordered by a broad belt of tule lands to the head of Tulare lake. Within the angle of the V mentioned lies what is known as Kern island, being mainly the delta of Kern river included between its ancient and modern channels, the former of which led directly into Kern lake, while the latter strikes Buena Vista slough.

Kern river, after leaving its precipitous cañon, flows mostly between gravelly bluffs of 100 or 200 feet high before reaching the valley proper. At this point it has been wont to spread in divers channels, seeking an outlet into the lakes, the distance from its present outlet to the mouth of the cañon being about 40 miles. From about 5 miles below the latter its bed is composed of shifting quicksands, varying in width from 150 to 800 feet. The banks are low, sandy, and unstable, and the land slopes rapidly away from them, offering great facilities for irrigation. Hence there is no other river in the state from which so many canals and ditches have been made to divert the water, their excessive multiplication giving rise to great waste of water. The higher lands bordering the eastern foot-hills, as well as the higher parts of the plains lands farther out in the valley, have not as yet been irrigated.

Details in regard to the alkaline character of some of these lands are given in the discussion following the regional descriptions. As a whole, they are highly productive, and have proved especially well adapted to the cultivation of cotton, though at present they are chiefly devoted to the culture of cereals and alfalfa.

The lands lying westward of Buena Vista slough and Tulare lake are reported to be very sandy, and few attempts at cultivation have as yet been made. Northward from the region irrigated from Kern river the sandy loam soils of the plains are but little cultivated as yet, but locally the foot-hill streams are utilized, and Tule river especially serves to irrigate a small but fertile district.

The *Kaweah river*, like the Kern, forms its delta far in advance of it, without reaching the great drainage trough, to which, indeed, it has not at present any definite channel. It begins to spread immediately after leaving its rocky cañon within the foot-hills, and loses a considerable portion of its waters in the beds of sand, gravel, and light alluvium with which it has built up the plain for many square miles in front of its point of emergence from the mountains. From the cañon to Tulare lake this river is 39 miles in length, falling, in that distance, from an elevation of 520 feet to that of the lake, viz, 190 feet above tide-water. In the upper portion of its course the grade is at times as much as 30 feet per mile, alternated with comparatively flat and swampy tracts, heavily overgrown with oaks and underbrush; but near the lake the plain falls only 2 or 3 feet per mile, and, without irrigation, is dry and barren. Down this sloping delta plain the Kaweah flood-waters find their way through eight or ten channels, whose beds are upon deep beds of sand, and are occasionally lost altogether in some swampy tract, the waters partially emerging below into another channel under another name. About half-way down the plain, from Cross creek on the extreme northwest to Outside creek on the southeast, the width of the delta is about 18 miles; but these channels approach each other lower down and enter the lake only 10 miles apart.

This, the Visalia region of Tulare county, is to a large extent heavily timbered with white oak (*Q. lobata*), and is the one wooded district of the San Joaquin valley; for elsewhere a few oaks, scattered widely apart, are all that is usually seen, and these are away from the main channels of the streams. The soils of the region vary considerably, from that of the sandy plains to a rich alluvial deposit, most of which contains some alkali, especially near the streams, but not usually enough to interfere with successful cultivation. From the numerous creeks irrigating ditches traverse the delta plain in every direction, leaving but little water unused, save in times of flood.

A belt of very strongly alkaline land about 2 miles wide borders the Visalia district on the west and northwest, but the impregnation becomes less as King's river is approached.

King's river, both from its location with reference to the adjoining country and from the volume and purity of its water, is one of the most important irrigation rivers of the state. Where it leaves the foot-hills all the water flows in a single channel, but in its passage through the adjacent "Centerville bottoms" its waters divide into several channels for a distance of 14 miles, and then again unite and remain confined to a single deep and tortuous channel the bed of which is from 20 to 65 feet below the surface of the adjacent plains. Practically, this portion of the river has no valley or bottom lands, the high bluffs encroaching generally upon the margin of the river. Here and there the bluffs recede, and the river is fringed with a narrow belt of alluvial land, covered with a scanty growth of oaks and vines. This condition is maintained to the head of Cole slough, where its waters are again divided, the greater part passing northward through the slough, and the rest along the old river channels, spreading into a delta-like swamp between Tulare lake and the San Joaquin river. King's river has not a single perennial tributary from the foot-hills to Tulare lake, a distance of about 62 miles.

South of King's river, and included between it and the tule lands bordering Tulare lake, lies the Mussel Slough country, so noted for its fertility, and which is irrigated by many ditches from the river, aggregating about 120 miles in 1880. The soil of the Mussel Slough country is mainly a light alluvial loam of great depth, evidently quite distinct from the soils of the higher plains. North of King's river its waters, taken from near its point of exit from the mountains, pass through numerous ditches (aggregating about 120 miles) to the plains of Fresno, lying considerably higher than the Mussel Slough country and possessing a very different soil—largely a whitish and very calcareous silt, quite unlike the plains soil of Tulare and Kern, but also yielding abundant returns when irrigated. The Fresno plains are gently rolling, almost exempt from alkali, and in spring present the appearance of a carpet of flowers. Near the foot-hills the red-clay soil of the latter has been mingled by the streams with the sand of the plains, making what is there called "red adobe". None of these streams cross the railroad, the plains to the westward being without any permanent channels and falling off gently into the long belt of "tules" that stretches between Tulare lake and the turn of the San Joaquin river.

The San Joaquin basin.

The *San Joaquin river*, on emerging from its cañon in the foot-hills, continues into the valley in a channel much depressed below the surface of the plains, and hence is, of all the rivers of the valley, the most difficult to draw upon for irrigation. For from 16 to 18 miles below the mouth of the cañon its water surface lies from 75 to 200 feet below the rolling plains, which frequently fall off to it in perpendicular bluffs. Hence, although the land to the southward is fertile and irrigates well, but little has been done in that direction. North of the river the foot-hills extend far down into the valley, and have a hard-pan subsoil, which sometimes lies almost bare and would not irrigate well. About midway to the trough, however, the soils are lighter and better suited to farming, and the river is more easily approached from either side, the plains being only 35 or 50 feet above the bed. To the southward the soils are mostly deep and rather sandy; but northward they are heavier, and their irrigation (water taken from the Chowchilla canal) requires great skill to prevent injury from excessive flooding, and are largely underlaid by a sandy and wholly impervious hard-pan. On the west side of the river the lands irrigated by the San Joaquin and King's River canal are very variable. For 35 miles from the great bend the land below it is for several miles a black, alkaline adobe, underlaid by a not wholly impervious, marly hard-pan, difficult to irrigate and till; but between Firebaugh's and Hill's ferries there are along the river large areas of sandy alluvial loam, readily irrigated and quite productive.

The *Fresno river*, or rather creek, about 12 miles north of the San Joaquin, is an intermittent stream, and about half-way to the trough is bordered by rough and rolling lands with an inferior soil. Below it passes through level land with a rich, sandy loam soil, and supplies a canal on the south side.

The *Chowchilla*, *Mariposa*, and *Bear* creeks, entering the plain from the foot-hills between the Fresno and Merced rivers, are intermittent streams, and flood the plain after heavy storms through numerous small channels, from which some of the water finds its way into the trough, while most of it is absorbed in the pervious soils of the region bordering the latter. Around and south of Merced city, between Deadman's and Bear creeks, there is a considerable body of black adobe lands, of which a narrow strip about 2 miles wide continues northwestward through Stanislaus county into San Joaquin, where this kind of soil is more characteristically developed.

Northward of Merced city a wide tract of "hog-wallows" comes in from the foot-hills, and is an excellent wheat soil in its level portions; but midway to the Merced river this tract rises into a foot-hills ridge, with a gravelly clay soil, that extends far out into the valley, and is of inferior quality. Toward the Merced river the soil again becomes lighter and productive, and is irrigated by a canal from the river.

The *Merced river* heads among the highest ranges of the Sierra, and, after traversing the Yosemite valley, passes to the edge of the plain through a deep, rocky cañon with a water-fall at its outlet. Thence its valley runs to the trough in nearly a straight line southwestward for 36 miles, but within it the river winds on a very tortuous course between abrupt bluffs as much as 3 miles apart and from 40 to 80 feet in height 8 miles below the falls, and thence narrows down within the next 8 miles to about 1 mile from bluff to bluff. These bluffs become still more contracted and less sharply defined as they approach the level of the plains on nearing the trough of the San Joaquin.

The wide lozenge-shaped bottom, terminating 16 miles below the cañon, is an important agricultural region, and is of especial interest in having been the sole locality of cotton-planting in the state for a number of years. The soil is a dark, sandy loam of great productiveness when supplied with moisture. At times of flood the water spreads from the main channels over the valley, frequently shifting its course permanently, cutting away large soil areas and covering them with coarse gravel. The soil is almost everywhere underlaid by such gravel at varying depths, sometimes coming close to the surface. Some levees have been constructed to prevent overflow and shifting, and it thus becomes necessary to irrigate the lands so protected. All the cotton grown here has, therefore, had the aid of irrigation.

The country between the Merced and the Tuolumne rivers is quite rolling near the foot-hills, the soil being generally sandy, resembling somewhat that of the Tulare plains, but on the whole less productive; on the other hand, the rainfall being greater, much grain is grown here without irrigation.

The *Tuolumne river* comes from the mountains through a most forbidding cañon, below which it is closely flanked by foot-hills, merging into rolling lands, and then into a plain lying from 50 to 80 feet above its water surface for 20 miles below the cañon. Thence the plain falls off toward the trough of the valley, so that the banks are only from 15 to 25 feet in height. For 30 out of the 42 miles of the river's course it is bordered by plains sufficiently even in surface to admit of irrigation on the large scale to advantage, having soils particularly adapted to its practice; and since in its habitual water volume the Tuolumne stands first among the rivers of the San Joaquin valley, its importance as a source of irrigation is very great, although thus far it has been but little utilized, the reason being that its bottom lands are very limited, and costly works are required to bring the water upon the high plains.

Between the Tuolumne and the Stanislaus the soil gradually changes from its very sandy character near the former river to a dark and more substantial loam of high productiveness.

On leaving the foot-hills, the *Stanislaus river* lies in a deep and generally narrow trough from 100 to 150 feet below the plains, its bottom being very narrow, rarely exceeding a few hundred yards, but having an excellent soil. In its lower course its slope is much less than that of the adjacent plains, so that within 10 miles of its mouth it lies but 40 or 50 feet below the plains level. Its immediate channel here is so narrow as to be altogether inadequate to carry the flood discharge, and hence the bottom is periodically overflowed. The soil of the plains adjacent to the Stanislaus is excellently adapted to irrigation, but the great depth of the river channel below the surface renders it necessary to locate the heads of irrigating ditches some distance up the cañon, and this is a costly undertaking. Hence irrigation is practiced on but a limited scale thus far; but in the deep, light loams a large amount of grain is grown without irrigation, and with comparatively few failures.

North of the Stanislaus to French Camp slough the land continues sandy, and is largely unproductive without irrigation. North of the slough, to and beyond the Calaveras river, lies the region of black adobe lands that constitute one of the most productive and densely-settled portions of the valley. Its surface is gently undulating, and is sparsely dotted with oaks. On the border of the tules, as well as at some other points, there are more or less interrupted belts of alkali land, mostly with a "hog-wallow" surface. The soil does not appear to differ materially from that of the adjacent lands, and by proper treatment it can doubtless be brought under profitable cultivation. (*a*)

The *Calaveras river* does not head high enough in the mountains to be perennial in its flow, the direct distance being about 25 miles from its point of emergence from the foot-hills to its junction with the San Joaquin river. At Bellota the stream forks, one channel, Mormon slough, passing westward through Stockton, the other, diverging to the northward, entering the San Joaquin about 5 miles northwest of Stockton.

Mormon slough is now the principal channel, and carries water when the northern branch is dry. In extreme floods both these channels are incapable of carrying the volume of water, and at such times the plains are extensively overflowed from the numerous side streams that put out from the main channels at weak points in their banks.

Before reaching the valley the water of the Calaveras is repeatedly used for mining purposes, and is always highly charged with fine sand and sediment; hence it is considered especially valuable when used in the irrigation of the heavier soils, the sandy sediment rendering the adobe more mellow and tractable.

Soils of the San Joaquin Valley.

As stated, the soils of the southern part of the great valley, even to the alluvial ones, are predominantly sandy, except in the main trough of the San Joaquin river; the sand being in most cases coarse. Exceptional in these respects are the fine silt soils of Fresno and the black adobe of southeastern Merced.

In the descriptions and tables given below the soils are segregated into upland or plains and lowland soils for convenience of consideration, but it must be admitted that the distinction is, of necessity, often somewhat arbitrary. Again, the two first mentioned (adobe soil and subsoil from Stockton) are much more closely related to the soils of Sacramento valley than to those of the San Joaquin, the characteristic sandy soils beginning some miles to the southward of the city of Stockton. True black adobe is, nevertheless, found again near and eastward of Merced city.

A.—Alluvial or lowland soils.

No. 6. *Black adobe soil* from S. 45, Weber grant, near Stockton, now the property of D. A. Learned, of San Joaquin county. This soil is dark-colored, very adhesive when wet, but in drying it cracks open at times to the depth of several feet. The sample was taken to the depth of 12 inches, the soil remaining the same. Its thickness varies from 6 inches to 4 feet, the latter coming nearest its average depth. The main body of this land lies between French Camp slough on the south and the Calaveras river on the north, extending 2 miles beyond the latter; westward it reaches to the alkali lands bordering the tules, while its eastward limit is not well defined, but lies at least 10 miles to the eastward of Stockton. The wheat product of this soil, when fresh, averages between 15 and 20 bushels per acre for five to eight years, and then decreases, but can be brought up by summer fallow and good cultivation.

No. 7. *Hard-pan subsoil* of No. 6, found underlying the black adobe in the lower ground at varying depths and of varying thickness, from 6 inches to several feet. This is a yellowish or whitish-gray, moderately coherent mass, more or less porous, which effervesces with acids, leaving a loose mass of sand and silt.

No. 195. *Valley soil* from a valley 2 miles south of the Merced river, Merced county, on the Hopeton and Merced road, through which the Farmers' ditch passes. This soil is a blackish-brown loam, easily tilled, and fairly representative of the soils of the smaller valleys of this as well as of the Dry Creek region.

No. 198. *Bottom soil of Merced river* from J. A. Grade's cotton plantation, near Hopeton, Merced county; a dark-colored, light loam soil, varying in depth from 18 inches to 5 feet, according to location, usually underlaid by gravel, which undulates more or less in subterranean ridges. Its chief natural growth is the California sunflower, which grows very luxuriantly, with some oaks and cottonwood on the lower ground. The bottom here is about 4 miles

a See article on alkali soils on page 63 for some details regarding this region and the general subject.

wide from bluff to bluff, and is traversed by numerous sloughs, as well as by gravel ridges. This soil in good seasons has made over 1,200 pounds of seed-cotton per acre, and a large body of it constitutes the Strong, Grade, and Buckley ranches, where cotton has been successfully grown for many years.

No. 570. "*Brown adobe*" *soil* from the lower land in the Eisen vineyard, near Fresno, Fresno county, taken to the depth of 12 inches; reddish brown, only moderately heavy, with much coarse sand intermixed, and easily tilled, except when very wet. This soil may be considered representative of the more substantial soils formed by the foot-hill creeks between King's and San Joaquin rivers in the shallow valleys, separated by divides of "sand-hill" ridges with very sandy soils.

No. 701. "*Dry bog*" *soil* from a valley on Sisson, Wallace & Co.'s land, 6 miles northeast from Visalia, Tulare county, in the "hog-wallow" hills; a black, heavy soil, occurring in the smaller valleys among the "hog-wallow" land. This soil is chiefly covered with long grass during the growing season, and, like the "adobe" elsewhere, is often deeply fissured during the dry season. It has usually at a depth varying from 6 to 18 inches a subsoil of heavy gray clay, with spots and concretions of bog ore, or "black gravel"; hence it is commonly ill-drained and needs drainage first of all. But little of it is cultivated. The analysis was made to determine its value for permanent culture when reclaimed.

No. 585. "*Wire-grass soil*" from wooded flats 2 miles west of Visalia, Tulare county. The soil is a gray or blackish, moderately heavy loam, characterized by a growth of wire-grass (*Scirpus*) and more or less of alkali grass (*Brizopyrum*), with alfilerilla. It is well timbered with oak. In low places occasionally a little alkali is visible on the surface, but there is not enough of it in the land to prevent the growing of cereals or other crops, and it is highly productive.

No. 579. *Alluvial loam soil* from near Grangeville, in the Mussel Slough country, Tulare county, and fairly representative of the best class of soils, yielding 46 bushels of wheat per acre. The soil is quite light and easily tilled, with no change of color for from 18 to 24 inches. Sample taken to the depth of 12 inches.

No. 77. "*Dry bog*" *soil* from the banks of Tulare lake, near its southeast corner, from overflowed land reclaimed by E. R. Thomason. This tract is inclosed by a levee, and lies below the high-water mark of the lake. Eighteen months previous it was all under water, but at the time of taking the sample the water was half a mile from the levee. The first vegetation that started after it was laid dry was "wild parsley", followed later by wire-grass, salt-grass, and tule. The surface at the present time shows no salt, and but little indication of alkali. Grain, however, "burns up" when hot weather comes, even though the ground be moist. Garden vegetables look well until blooming time and then die. When sampling the soil at the time stated it was found to be baked quite hard for the first 6 inches; but from that line down to 20 inches, to which depth it was taken, it was "boggy and soft". The soil as received is a somewhat bluish-gray clayey sediment, containing a good deal of small gravel and shells intermixed. Its reaction is alkaline, though not sharply so.

B.—Upland or bench soils.

No. 193. *Loam soil* from the "hog-wallow" tract 5 miles north of Merced city, Merced county, near Huffman's wheat farm; a reddish or brownish loam, rather close and coherent when dry. Sample taken to the depth of 12 inches. The subsoil is nearly of the same character for 3 feet. The surface of this land lies in gentle swells, on which are the characteristic "hog-wallow" hillocks, not very deeply impressed, and therefore not interfering materially with plowing even in fresh land, and almost disappearing after a few years' tillage. The wheat product is from 25 to 30 bushels per acre in fair years on fresh land.

No. 704. *Fresno plains soil* from Mr. White's place, Central colony, about 2 miles south of Fresno city, Fresno county; a grayish-white, somewhat ashy soil, changing little to the depth of 2 feet or more, then gradually becoming more sandy, sometimes underlaid at a depth of from 1½ to 3 feet by a sheet of calcareous hard-pan, from 8 to 18 inches in thickness, which seems to be merely the subsoil cemented by lime. In planting trees it is sometimes necessary to break through this hard-pan in order to enable the roots to reach moisture. This soil is said to be fairly representative of the country lying to the southward and westward toward King's river and the San Joaquin. To the east and north it passes into the reddish and "sand-hill" soils formed by the streams coming from the foot-hills. (See soil No. 570, from the Eisen vineyard.)

No. 586. *Tulare plains soil*, taken midway between Outside creek and the Sierra foot-hills east of Visalia, Tulare county. Depth taken, 12 inches, with apparently little change for several feet. The tract is quite level, and is treeless. This land does well when irrigated, but has thus far been taken into cultivation less freely than the lands lying nearer the creeks. It is said to be a fair sample of the "plains" proper of this part of the San Joaquin valley, and is of a dun color, quite light and sandy, and not altogether promising in appearance, but bearing a luxuriant growth of wild flowers, which testifies to its productive capacity.

No. 573. *Tulare plains soil* from near the crossing of Cross creek, on the Visalia and Hanford road, Tulare county, taken to 12 inches depth. This soil resembles the preceding, but is of a more grayish tint when dry and darker colored when wet, as a result of its proximity to the creek, which, however, rarely carries water, so that the soil can hardly be accounted an alluvial one. There are decided indications of alkali in the lower portions, and this is more clearly perceptible where the soil has been cultivated with irrigation, as is the case within a mile or two farther to the west. The country is altogether treeless, but in spring-time bears a luxuriant growth of bright flowers.

No. 700. *Salt-grass soil,* forming a belt on the western edge of the plains east of Buena Vista slough, Kern county; a yellowish gray, fine sandy soil, nearly the same in character to a depth of several feet. Sample taken to 12 inches. Much salt-grass, and but little herbaceous vegetation beside. When irrigated, this soil produces as much as 40 bushels of corn to the acre. It has been but little cultivated thus far, being chiefly pastured.

Alluvial or lowland soils of the San Joaquin region.

	SAN JOAQUIN COUNTY.		MERCED COUNTY.		FRESNO COUNTY.	TULARE COUNTY.			
	NEAR STOCKTON.		FARMERS' DITCH.	NEAR HOPETON.	NEAR FRESNO.	NEAR VISALIA.		NEAR GRANGEVILLE.	
	Black adobe soil.	Hard-pan; subsoil of adobe.	Valley soil.	Bottom soil, Merced river.	Brown adobe, Eisen vineyard.	"Dry bog" soil, "hog-wallows."	"Wire-grass" soil.	Alluvial soil, Mussel slough.	"Dry bog" soil, Tulare lake.
	No. 6.	No. 7.	No. 195.	No. 198.	No. 570.	No. 701.	No. 585.	No. 579.	No. 77.
Insoluble matter	} 72.058	64.903	75.405 } 88.691	73.120 } 77.002	76.622 } 79.492	67.519 } 71.778	66.470 } 71.420	79.518 } 82.737	67.34
Soluble silica			8.286	3.882	2.870	4.259	4.950	3.219	
Potash	0.396	0.248	0.423	0.569	0.714	0.562	1.224	0.700	1.05
Soda	0.470	0.404	0.125	0.094	0.444	0.657	0.677	0.286	0.84
Lime	1.927	8.502	0.758	1.316	1.769	2.599	3.043	1.246	6.51
Magnesia	1.640	2.700	0.621	0.547	2.048	0.753	0.087	1.578	3.96
Brown oxide of manganese	0.056	0.034	0.038	0.036	0.041	0.066	0.030	0.018	0.04
Peroxide of iron	6.816	5.672	4.452	9.078	3.728	5.599	5.823	4.030	5.05
Alumina	11.620	6.252	6.331	5.090	7.988	12.395	7.137	6.578	7.97
Phosphoric acid	0.179	0.324	0.048	0.132	0.038	0.074	0.239	0.069	0.32
Sulphuric acid	0.037	0.056	0.046	0.094	0.074	0.145	0.655	0.019	0.08
Carbonic acid	...	6.229	...	...	...	0.083	2.546	...	4.42
Water and organic matter	5.871	4.860	3.882	5.991	3.244	4.495	7.091	3.049	3.71
Total	101.078	100.184	100.415	99.949	99.580	99.206	99.972	100.310	101.29
Humus	...	...	0.867	1.800	0.597	1.061	...	0.644	0.468
Available inorganic	...	...	0.595	0.563	0.873	0.984	...	0.587	2.184
Available phosphoric acid	...	...	...	0.130	0.020	0.039	...	...	...
Hygroscopic moisture	...	...	5.480	5.671	5.430	11.194	8.530	3.889	...
absorbed at	...	...	...	...	...	...	...	...	15 C.°

Upland or bench soils of the San Joaquin region.

	MERCED COUNTY.	FRESNO COUNTY.	TULARE COUNTY.		KERN COUNTY.
	Loam soil, "hog-wallows", 5 miles north of Merced.	Central colony, Fresno plains soil.	Plains soil, Outside creek.	Plains soil, Cross creek.	Salt-grass soil, Buena Vista slough.
	No. 193.	No. 704.	No. 586.	No. 573.	No. 700.
Insoluble matter	80.328 } 84.673	85.874 } 88.579	73.774 } 77.265	66.079 } 69.457	87.060 } 89.040
Soluble silica	4.345	2.705	3.491	3.378	1.980
Potash	0.347	0.340	1.221	1.817	0.492
Soda	0.058	0.248	0.149	0.436	0.305
Lime	0.508	1.163	1.173	4.307	1.198
Magnesia	0.588	0.499	1.751	1.585	1.069
Brown oxide of manganese	0.016	0.034	0.027	0.078	0.025
Peroxide of iron	4.772	3.276	5.073	6.041	5.822
Alumina	6.165	3.221	7.799	8.692	0.171
Phosphoric acid	0.023	0.097	0.103	0.138	0.079
Sulphuric acid	0.006	0.117	0.003	0.263	0.133
Carbonic acid	...	...	...	2.533	...
Water and organic matter	3.278	1.789	4.351	4.150	1.130
Total	100.434	99.363	99.515	99.497	99.464
Humus	0.367	0.604	1.139	0.996	0.170
Available inorganic	0.334	0.351	0.535	0.740	0.195
Available phosphoric acid	0.019	0.011	...	...	0.009
Hygroscopic moisture	4.212	2.217	4.618	8.735	2.164
absorbed at	15° C.	15° C.	15° C.	15° C.	15° C.

A glance over the preceding tables of soils of the San Joaquin valley shows at once that, like those of the Sacramento division, they nearly all agree in having a large percentage of lime; in only one case as little as half of one per cent., in most cases over and ranging as high as 3 per cent.

All these soils, except the Stockton adobe, are of a rather sandy or light character, which places them the more distinctly in the class of calcareous soils, and this accounts for the extraordinary thriftiness, when placed under irrigation, of even such as do not show high percentages of phosphates and potash. Thus, in No. 193 (Merced hog-wallow soil) the potash percentage is quite low for California, while that of phosphoric acid is exceedingly low; yet these soils have yielded from 16 to 25 bushels of wheat per acre for several years consecutively. They will doubtless, however, soon require the use of bone-meal for the maintenance of production. The same deficiency of phosphoric acid occurs in the bottom soil No. 195, also from northern Merced. Almost throughout, the percentage of phosphoric acid in the soils of the San Joaquin valley is only moderately high, many falling below one-tenth of one per cent. and only two rising above two-tenths. These latter are Nos. 585 and 77, both alkaline soils, in which probably the soluble phosphates have accumulated near the surface (from which the sample was taken), doubtless, in part at least, at the expense of the surrounding uplands. It follows, that while in the lowlands that are more or less impregnated with alkali both potash and phosphates are comparatively abundant and will not require replacement for a long time to come, in the uplands the phosphates will be the first to become exhausted, when bone-meal and superphosphates will come into heavy demand. On the other hand, the use of lime as a fertilizer will scarcely ever be called for in the San Joaquin valley, and potash manures will not be needed for a long time to come, even in the uplands, and never in the lowlands.

It is important to note this corroboration of the opinion expressed in a previous report (*a*) as to the superior value of the "alkali soils" when once properly reclaimed and cultivated with a view to the repression of the "rise of the alkali" to the surface; for we find that, with the worthless or injurious excess of salts, there is almost always associated a large supply of soluble or at least available plant-food, which will render these soils remarkably durable and thrifty.

For the discussion of the measures and precautions needed for the reclamation of alkali soils the reader is referred to pages 63 to 73.

There is another point shown in these analyses worthy of note. The traveler on the San Joaquin plains will, during the dry season, imagine that the gray dusty soil of the plains is destitute, of or at best very poor in, humus or vegetable mold. The figures given in the table show that this is far from being the case, for even the white soil of the Fresno plains shows six-tenths of 1 per cent. of humus, and that of the sandy Tulare plains 1 per cent. and over. It is here again the lime, so abundant in these soils, that helps to retain the humus, despite the prolonged action of the hot summer's sun. Of the soils examined, two only are really deficient in humus, viz, No. 193, the Merced hog-wallow, and No. 700, the salt-grass soil of Kern. In the case of the latter the alkali present dissolves the humus and allows it to be washed away into the sandy subsoil below, and this happens more or less in all alkali soils containing much carbonate of soda. It is therefore doubly important that this ingredient should be gotten rid of by the use of gypsum when such soils are put under cultivation, especially with irrigation.

In the case of the Merced hog-wallow soil, the poverty in humus is obviously attributable to its "hard-pan" nature, through which, in its natural condition, the mold remains on the surface, and is "burnt out" by the sun during the dry season. The thriftiness of such soils would doubtless be very much increased by plowing under some green crops.

As to retentiveness of moisture, there are but two soils in the list that fall below the limit usually deemed desirable. One of these is the white plains soil south of Fresno (No. 704), and the other is the salt-grass soil (No. 700) from Kern. The latter is notably deficient both in humus and clay, and what moisture it does retain is probably partly due to the alkali present. In the Fresno soil, considering the amount of alumina shown in the analysis and the humus present, the moisture absorption is unexpectedly low and in urgent need of being raised by means of green-manuring. It will also be especially advisable that, wherever the crust of hard-pan underlies the soil at a depth of less than three feet, that impervious layer should be broken up or through, in order to enable the roots to seek for moisture at the depths allowed them by this very easily penetrable and deep soil.

This great depth of soil, which is observable more or less over the whole of the San Joaquin valley, is of the utmost importance with respect to the permanence of productiveness; for the soils being mostly very pervious and loose, and the water-table, even where irrigation is practiced, quite low, the plant is enabled to draw for its food upon a much greater mass of soil than would be the case where the latter is heavier and perhaps richer in plant-food but less easily penetrated by the roots than are sandy soils. In the case of the San Joaquin soils, moreover, examination shows that much of the sand is not quartz, but pulverized rock still in process of decomposition and soil formation.

Soil No. 77, from the land left by the recession of Tulare lake, presents a peculiar phase of the "alkali soil" question, which is discussed more in detail on page 69. The results of the mechanical analysis, given on page 83, show this soil to be within the limit of moderately clayey ones, and, considering the large amount of lime present and the uniform

a Report of the California College of Agriculture, 1879, page 35.

distribution of sediments, it ought to till well. The chemical analysis, so far as the chief ingredients of mineral plant-food are concerned, shows the general composition of the soil to be excellent. The amounts of potash and phosphoric acid are equal to those of the most productive soils of the Yazoo bottom, and the large percentage of lime should insure thriftiness. But it is evident, from its alkaline reaction and the large percentage of soda shown in the analysis, that it contains enough of true "alkali" to interfere seriously with tillage as well as with the welfare of vegetation. At the same time the solution formed by hydrochloric acid showed the want of aeration in giving an indication of iron protoxide. These inferences are corroborated by the observations made by the owner of the tract, that wheat made some fine ears on the upper part of the levee, where, of course, the rain had washed out some of the alkali, and where also the air had free access. It was therefore recommended that the land be given a full dressing of plaster to neutralize the carbonate of soda, and that it be well and deeply fallowed; but a subsequent investigation having shown that the water of Tulare lake is not available for irrigation on account of an excessive percentage of alkali of similar character, the reclamation project was for the time abandoned. Considering the great native fertility of this soil, the reclamation of the wide belt of similar land that surrounds the lake and is constantly widening by its recession would be a matter of great importance to the state, and is well worthy of further experiment. Success is, of course, dependent on the command of an adequate supply of irrigation water, but whether from King's river or from artesian wells is a question for future determination. Taking all the evidence of possible productiveness in this portion of the great valley, the importance of utilizing fully and economically the water resources of the adjacent mountains cannot easily be overestimated.

TULE LANDS.

This is the name applied in California to all lands, whether littoral or inland, bearing as an important ingredient of its vegetation the tule or rush, which, of course, varies in kind according to location near to or remote from saline tide-water. In the coast marshes the tule is prevalently the rush, properly so called (*Scirpus lacustris*), while the tule of the fresh-water marshes in the upper portion of the delta of the Sacramento and the San Joaquin, as well as in the upper portions of the courses of these rivers, consists largely of other species, notably the cat-tail rush (*Typha*). All these lands are, of course, subject to overflow, and need protection by levees.

The surface of the marsh lands is covered with a matted mass of roots from one foot to several feet in depth, in all stages of decay, the lower portion being in a peaty condition, and sometimes available for the manufacture of peat. Occasionally this mass is afloat, so as to rise and fall more or less with the water; in most cases, however, a solid sediment soil of high productiveness underlies the roots at a moderate depth.

The prevalently bold and rocky coast of California presents but few and small marsh areas outside of the great valley and bay regions. On San Francisco and San Pablo bays the tule lands do not differ materially from the salt and brackish marshes elsewhere, and their reclamation is effected by similar methods. Passing Carquines straits, however, we come upon a wide expanse of marsh, in which the water is fresh, or only slightly brackish in the lower portion. These tule lands constitute here the delta of the two great rivers of the valley, whose numerous sloughs and creeks form an intricate network of meandering channels, through which only a practiced native can find his way to a definite point. They form a large body to the northward of Suisun bay, and then, after narrowing for 10 miles to a width of 3 or 4 miles, they expand to a broad belt, which covers the western part of San Joaquin and Sacramento counties, and thence continues northward along the Sacramento river far into Colusa county. To the southward they form only narrow and interrupted belts along the San Joaquin river until we reach the basin of the upper valley, where long belts of tule lands, 5 or 6 miles in width, extend northwestward and southeastward from Tulare lake, and also form a broad rim around that lake itself.

The tule lands of the Sacramento valley differ in several important points from those of the Tulare basin and of the San Joaquin valley generally. The latter are mostly strongly tainted with alkali, and on that account are somewhat difficult of reclamation, although of high fertility when reclaimed. The more abundant rainfalls and drainage of the Sacramento valley practically obviate this difficulty in the case of the northern tules, the sole question being that of drainage and the exclusion of overflows.

The soil of the Sacramento valley tules, when reclaimed, is mostly of the character of adobe, mingled more or less with the fine river sediment, resembling so closely the soils of the adobe belts, now largely above overflow, as to create the presumption that the latter indicate the areas over which tule swamps extended in ancient times. At high stages of water in winter and spring the tule areas are, as a rule, submerged to varying depths, the exception being the singular "float-land", of which tracts sometimes several acres in extent rise and fall with the water occasionally as much as 3 and even 4 feet, serving at times as a place of refuge for cattle. In such spots the matted mass of tule roots and decayed stems is found to be from 8 to 12 feet in thickness, with no solid bottom, but simply water immediately beneath. They are chiefly found in the lower portion of the San Joaquin delta.

Where the round rush or tule (*Scirpus lacustris*) chiefly prevails solid ground is commonly found immediately beneath the mass of tule roots at a depth varying from 18 to 24 inches, and sometimes even more. In the dry climate of the region these roots decay very slowly, hence, where of great thickness, they are frequently set on fire during the dry season; their ash serves to still further enrich the underlying soil while at the same time rendering it accessible to the plow. It has been, and is even now, a not uncommon practice to sow the grain into this ash the first season and then have it trodden in and the ground compacted by sheep, and in favorable seasons crops of wheat thus grown have reached the enormous yield of 80 bushels per acre.

Such results could not fail to excite great interest in the reclamation of the tule lands, and much capital has been invested in leveeing and draining large tracts, especially in San Joaquin and Sacramento counties. Since the natural moisture of these lands renders irrigation unnecessary, grain crops on them are assured, provided the overflow be excluded, and are generally best in seasons when, from want of moisture, crops fail in the unirrigated uplands. Much difficulty is sometimes experienced in levee building from the lack of material of sufficient weight to resist the buoyant pressure of the water, which will not only filter through the tule sods when used for the purpose, but has occasionally floated the levee bodily down stream.

So far as not reclaimed for cultivation the tule lands serve during the dry season as an eligible pasture ground for cattle, and more or less at all times, but especially during winter, as a resort for innumerable water-fowl (notably geese and ducks), which often commit severe depredations upon the adjacent grain-fields.

Among the more important portions of the northern tules that have been successfully reclaimed is a number of "islands" lying between the San Joaquin and the Sacramento, viz, Union, Roberts, Staten, Boulder, Rough and Ready, Sherman, Brannan, and Andrus. On these nearly every product adapted to the climate is successfully cultivated; and, contrary to expectation, human health on reclaimed tules is on the average better than on the adjacent bottom lands. At some points, notably on Suisun bay, there appears to be "no bottom" beneath the sod, and the road-bed of a branch of the Central Pacific railroad crossing this marsh has again and again disappeared under the surface over night or behind a passing train, and thousands of car-loads of gravel and rock have sunk out of sight without apparently definitively filling the "bottomless pit".

The tule lands of the upper San Joaquin valley have not as yet been reclaimed to any great extent, partly, as before stated, on account of their alkaline character. The soils mostly contain a large amount of coarse sand, which, however, does not prevent their having the character and name of adobe. Much of the land now being laid bare by the recession of Tulare lake is of exuberant native fertility, as is shown by the analysis given on page 28 (see No. 77), but can be made practically productive only by the neutralization and partial removal of the alkali. Small tracts so reclaimed have fully justified in their production the presumption created by the analysis. The natural pasture, however, can be, and is, freely utilized, it being noted that hogs especially fatten quickly upon a diet of succulent tule roots. The following description is from Mr. Sherman Day, formerly of Bacon island:

Float-land sod.—This reaches to an unknown depth, perhaps from 7 to 10 feet, but at 10 feet the hard bottom is not reached, only slum and water. Probably hard sandy bottom would be reached at from 24 to 28 feet from the surface. In dry seasons the seepage water reaches to within 2½ feet of the surface, but in rainy seasons it stands within from 1 to 6 inches of the surface.

The sod of the *heavy round bulrush land* is characterized by the large woody or corky roots diffused through the mass of smaller fibrous roots of the grasses. Besides the large tule roots, there are sometimes the still larger roots of the pond lily. Below them is the mass of soil and fibrous roots, interspersed with a few of the corky roots. The seepage water is usually about 3 feet below the surface when the levees are in proper condition. The depth of the soil is not known. Furrows are run in this 4 or 5 inches deep, and when the furrow sods have dried for six or eight weeks they are set on fire and burned down very evenly to the depth of the furrow and a trifle below, according to the absence of moisture. This kills the heavy tule roots and checks the growth of grass. The seed is then drilled in under the ashes after they have become wet by the rain, or it is trodden in by bands of sheep. The ashes leach about enough the first year to correct any acidity of the peaty sod, but their principal function the first year seems to be as a mulch to shade the soil during the early growth of the plant. If the seed is not pushed down so that its first roots take hold of the black soil, the blackbirds pull up the plumule from the loose ashes. The crops thus sown under the ashes are usually very abundant, having scarcely any competition from weeds. Sometimes a volunteer crop is gathered the second year, but, as a general rule, these crops carry too many weeds to do well on the tule lands. The ashes are usually plowed under the second year.

The coarse bulrush and underlying sods make but little progress toward decomposition by mere exposure to the atmosphere; the float-lands decompose more readily.

THE FOOT-HILLS OF THE SIERRA AND NORTHERN COAST RANGE.

The western slope of the Sierra Nevada mountains embraces a belt of country falling in elevation from 4,000 feet at the foot of the mountains westward to less than 500 feet at the border of the great valley of Sacramento and San Joaquin, and varying in width from 50 to 70 miles on the north and center, but becoming very narrow on the south. The higher portion of this belt, immediately along the foot of the mountains, and from 4,000 down to 2,000 feet altitude, possesses many of the characteristics of the Sierra range in its high, mountainous, and extremely broken surface, and is therefore described as a subdivision of that mountain region. The remainder of this belt, or that having an elevation of about 2,000 feet down to that of the great valley, is distinct in its topography, climate, and agricultural features, and is that to which the designation of *Sierra foot-hills* has been given.

This belt, with the same characteristics, continues around the head of the Sacramento valley, in Tehama county, forming there a region of *Coast range foot-hills*, which, from similarity of soil, may be considered as continuing in a narrow belt southward into western Yolo county.

These foot-hills of the two ranges of mountains are estimated to cover an area of about 11,700 square miles. The Sierra belt has a width varying from 30 to 40 miles from Shasta southward to Mariposa county, and thence is very narrow, usually about 5 miles, widening in Kern, and terminating, with the Sierra, against the Coast range near

Tejon pass. The following counties and parts of counties are included in the belt of Sierra foot-hills: The middle and southern parts of Shasta, most of Tehama, eastern parts of Butte and of Yuba, the western parts of Sierra, Nevada, Placer, El Dorado, Amador, Calaveras, Tuolumne, and Mariposa, small strips along the eastern edge of Sacramento, San Joaquin, and Stanislaus, and a narrow belt southward from Mariposa through Fresno, Tulare, and Kern.

The foot-hills of the Coast range occupy a broad region in the western part of Shasta and Tehama counties varying in width from 10 to 40 miles; but in the western part of Colusa county it suddenly contracts, and southward to Cache creek, in Yolo county, its width varies from 6 to 10 miles, and often less, while still southward to the bay the hills occur as outliers to the Coast range.

While more or less adapted to all the products grown in the valley, the foot-hills are now noted as a fruit-growing region, and probably will be still more noted in the future, including, especially in its northern part, the very successful culture of the vine.

THE FOOT-HILLS OF THE SIERRA.

A line marking the separation between the foot-hills and the great valley would pass from the Sacramento river, north of Red Bluff, in Tehama county, southeastward to the following principal points: 3 miles east of Chicot and a short distance west of Oroville, Butte county; 10 miles east of Marysville to Rocklin, Placer county, and Folsom, Sacramento county, and thence southeastward, nearly following the county-lines, via Knight's ferry and Merced Falls, to Fresno county.

This region is watered by many streams, that cross it from east to west in their course from the mountains to the great valley, joined by many small tributaries from the region itself. Cutting their way, as they do, in narrow cañons or valleys between the hills, they have, as a rule, but little bottom land, and even then, because of their liability to floods during the rainy season, these lands are often not available for farming purposes. These streams have been more fully described on pages 19 to 21.

The foot-hills of the Sierras are properly divided into three separate and distinct regions, differing in their topographical and lithological as well as in their agricultural features. These are a barren *lava-bed region* on the north, a *granitic region* adjoining this and also on the extreme south of the foot-hills, and a central or auriferous region, the real *foot-hills* of the eastern side of the state. These subdivisions are best described separately.

THE AURIFEROUS BELT, OR FOOT-HILLS PROPER.—The foot-hill region of the Sierra is known as the gold belt of the state, for here most of the mining operations have been carried on and the greater part of the metal has been obtained that has given to the state its prominence in this regard.

The gold-bearing rocks comprise a belt of from 10 to 25 miles in width, reaching from Butte county southeastward into Mariposa, and embracing metamorphic slates and sandstones. North of the belt these rocks are covered by lava beds and other volcanic material.

In the extreme southern portion of the gold region, beyond Mariposa county, the slates almost cease to form a continuous belt, and they are more and more encroached on by the granite as we go toward the Tejon. In fact, there is a gradual decrease in the width of the auriferous formation proper from the north toward the south and a constant increase in the amount of metamorphism displayed, the granite occupying a larger portion of the mass of the Sierra and descending lower down its flanks, while the crest of the mountains becomes more and more elevated, its culminating point being in about the latitude of Owen's lake.—*Report Geological Survey of California.*

The eastern part of the region is well timbered, much broken, and very sparsely populated; the western is thinly timbered, but, being less broken and better adapted to cultivation, contains nearly all of the population.

The following description is taken from a paper by B. B. Redding, esq., read before the California Academy of Sciences:

At the northern end of the valley, at an elevation of 500 feet above the sea, are found *Quercus lobata, Sonomensis, Wislizeni, chrysolepis,* and *Douglasii*, of the California oaks; of pines, only the nut or digger pine (*Pinus Sabiniana*); the buckeye (*Æsculus Californica*); and chamisal (*Adenostoma fasiculata*). (*a*) This is the characteristic arboreal vegetation throughout these 350 miles. Its presence everywhere shows increased rainfall over the valley and similarity of temperature to that of the valley. Our pasture oak (*Quercus lobata*) is found at lower elevations in the valley, but always on moist land or near river courses, proving that it demands, in addition to temperature, the increased moisture. In the southern end of the valley this vegetation prevails at higher elevations, because it there finds the proper temperature and moisture. Wherever on the foot-hills any of the trees named constitute the predominant arboreal vegetation, it is evidence that the temperature is the same as that of the valley, and that plants that can be successfully grown in the valley can be grown to as high an elevation on the hills as these trees abound. If one tree were to be taken as the evidence of this uniformity of temperature, it would be Sabin's (the nut or digger) pine. It is never seen in the valley or on the hills below an elevation of about 400 feet. It is not found at a higher elevation than that in which the temperature is the same as that of the valley. It is never found in groves, but singly among other trees; yet it prevails throughout these 350 miles of foot-hills.

While the vegetation is more dense on the hills at the northern end of the valley, due to increased precipitation, there are also local differences, where there is similarity of soil, due to exposure. Throughout all the lower hills the greatest number of trees is found on gently sloping eastern, northeastern, and northern hills, which necessarily are more moist and cool. The southern aspects contain less trees, because exposed to the direct rays of the sun and to the full force of the prevailing winds.

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a To these should be added, in the northern portion especially, the manzanita (*Arctostaphylos Andersoni, pungens, tomentosa*) and several species of chaparral (*Ceanothus*, notably *C. crassifolius, cuneatus*, and *thyrsiflorus*, the latter more particularly to the southward, where it is so abundant as to serve for fencing).

Every agricultural product that can be grown in the valley, including the semi-tropical fruits, can be grown with equal facility in these foot-hills. Ordinarily the land has to be cleared of the trees found upon it, and cultivation must be continuous; for on the whole western face of the Sierra the native trees, when cut or burned down, are rapidly replaced by a new growth of the same kinds.

These lands are found to have all of the requisites for the successful growth of orchards. Fruit trees thrive better upon them than on the lands of the valley. None of the many theories advanced as to the cause of the treeless condition of many plains and prairies having ample rainfall seem to be entirely satisfactory, but experience has demonstrated that orchards grow best and thrive with less artificial aid on lands that in a natural condition are covered with trees.

The increasing exports of small fruits, such as strawberries, blackberries, and raspberries, from the vicinity of Newcastle and Auburn, and their superior size and quality, prove that this region is better adapted to their culture than any place yet found on the level lands of the valley. The peaches of Coloma have a stall reputation for flavor and size. The apples of Nevada and Georgetown are equal in size, taste, and keeping qualities to the best imported from Oregon. The Oroville oranges have been pronounced equal to the best of Los Angeles. The vine grows with luxuriance and bears abundantly wherever it has been planted throughout all this region. The wines of Coloma have more than a local reputation. Persons competent to judge assert that wine from grapes grown on the foot-hills is free from the earthy taste that characterizes much of the wine of the flat land of the valleys. They also express the belief that if ever wine is to be made in California as light as that from the Rhine and as free from alcohol, the grapes will be grown in the higher elevations of the foot-hills, where snow falls and remains on the ground a few weeks each season. It is said that the long summers and great heat of the valleys develop the saccharine matter in the grape, which, by fermentation, is converted into alcohol.

In Butte county the line separating the foot-hills from the great valley is well defined, the surface of the former being not only undulating, but broken and barren, and with an abundance of bowlders. For the first 8 or 9 miles eastward the soil is said to be thin and volcanic in character. All of the lands of the region are red and gravelly, mostly destitute of trees, and on the hills barren, those of the valleys being best suited for cultivation.

In Yuba county the country near the valley is at first rolling, but it becomes more and more hilly, rocky, and brushy to the eastward. The soils of the western part are chiefly red and pebbly clays, and on the lower hills are well adapted to fruit trees and vines. These red lands reach across Nevada county, interspersed with granitic lands, into Placer, where they are the prevailing soil on the broken hill country from the foot of the Sierra to the belt of granite 2 miles west of Auburn. The timber growth is white, live, and black oaks, buckeye, and chaparral.

In the counties southward the same general features are seen: a low, rolling country, sparsely timbered with an oak growth, rising into higher and more heavily timbered hills toward the Sierra mountains. The soil is also a reddish or brownish loam, tillable, however, only in the valleys or on the low hills of the western part of the belt. Lumbering is the chief industry in the eastern part of these counties, and as a matter of interest concerning the timber growth the following extract from a letter of a correspondent of the *San Francisco Bulletin* is given:

The timber belt of Mount Diablo parallel commences on the Stanislaus river, 40 miles east of Stockton, by the appearance of straggling oaks on the bluffs, which are from 40 to 150 feet above the water. As the rock-bound surface gradually rises these trees attain a larger size and become more numerous, especially in depressed locations, where deposits of soil have been made. In no place within sight, until reaching Chinese Camp, is there an average of over one acre of well-timbered surface to the square mile. At Chinese Camp the digger or nut pine begins to appear, interspersed among the oaks. The surrounding hills have before this begun to assume the magnitude of mountains, near the middle and rounded top of which this tree may clearly be distinguished in the distance. From Chinese Camp to Columbia, 16 miles, there is no material change in the sylvan vegetation, except an increasing density of this pine growth, with an occasional appearance of Sabin's pine. Columbia may be considered the starting-point of the great pine forest which extends east to the upper foot-hills of the Sierra, 60 miles. The southeast limit of this range is said to terminate at Yosemite ridge, below which the timber is in patches; to the northwest it extends into Oregon. Besides the pines, cedars occupy a prominent position in the sylva of this belt; commencing at an altitude of 4,000 feet, they gradually increase in numbers, till in some spots they have precedence of all others. The black oak is interspersed in moderate quantities among other trees.

A prominent feature in the topography of Amador, Calaveras, and Tuolumne counties is the occurrence of belts of lava-capped hills and mountains, as well as deposits of other volcanic material, the remains of what were once lava flows from the Sierra mountains westward. Table mountain, rising some 2,000 feet above the Stanislaus river, has a length of about 30 miles, its flat top being from 1,200 to 1,800 feet wide. At Texas Flat, Tuolumne county, there is a vast accumulation of calcareous tufa formed over the auriferous gravel in an ancient gulch emptying into the Stanislaus river, where it rises in picturesque cavernous cliffs resembling coral reefs. In this tufa are found the bones and teeth not only of the mastodon, elephant, and other gigantic animals, but also of the horse and other mammalia, together with land and fresh-water shells.

In Mariposa county the foot-hill region is narrow and its hills low and tillable, though but little farming is done. The soil of the hills is a reddish clay, while the valleys are covered with a dark loam.

THE GRANITIC REGION.—A belt of granite having a width of about 10 miles reaches from Feather river southward through Butte, Yuba, Nevada, and Placer counties into El Dorado county and the northeastern corner of Sacramento, near Folsom. In Nevada county especially this rock is very abundant, outcropping in large areas, the chief belt passing a little east of Grass valley, northward by San Juan, to Feather river. The rock appears in large masses and in weathered bowlders, giving rise to sandy and gravelly lands, while the surface of the country is broken into the rounded hills characteristic of granitic regions. Southward in other counties as far as Mariposa granite appears occasionally in smaller belts, and outcrops among the slates and metamorphic rocks of the foot-hills. Still southward from Mariposa to the limit of the foot-hills it is the prevailing rock, with a bordering narrow belt of slate, which, with its occasional capping of Tertiary sandstone, gives to it a broken character, its valleys being covered with sand and gravel.

REGION OF LAVA BEDS.—The lava beds cover nearly the entire foot-hill region north of Feather river, Butte county, reaching also far northward across the Sierra region to the Oregon line, their western limit being the

Sacramento river. The region is described on page 62 as a subdivision of the Sierra mountain region. The lava beds are said to terminate not far from the river in abrupt edges, the plains below being also covered with volcanic fragments. The streams have cut their way through the lava, in gorges some 200 feet deep, into the Cretaceous beds that underlie it. The surface of the lava bed is usually destitute of vegetation and of soil of any depth. In Shasta county, between Cow and Bear creeks, the hard lava gives place to a broad plain of volcanic ashes, which is said to be almost destitute of trees and bare of herbage, and, as yet, hardly eroded into cañons.

Very little of the entire lava region is suitable for cultivation, though some of the streams have a little fertile bottom land.

In Tuolumne and adjoining counties there are other table-lands and hills of basaltic lava, which form a prominent feature of those counties. They are described in connection with the Sierra mountain region.

THE FOOT-HILLS OF THE COAST RANGE.

Assuming the Sacramento river to be the dividing line between the foot-hills of the Sierra and those of the Coast range in Shasta and Tehama counties, we find the latter region occupying a large area in the southwestern and western portions of those counties, the maximum width in Shasta being about 35 miles. Its surface is rolling and broken, interspersed with many small valleys, and is but sparsely timbered. These hills are too broken for cultivation, and the farms lie chiefly in the valleys. The soil is mainly a red and gravelly loam, and when under cultivation yields good crops of grain. The higher valleys are mostly devoted to grazing purposes. This region is well watered by many streams, which, rising on the Coast mountains, flow eastward into the Sacramento river.

In Colusa county the foot-hills become more and more broken toward the foot of the Coast range, and are partly covered with an oak growth and partly with laurel, manzanita, and chaparral. The cultivable land lies chiefly in the several valleys among the hills, viz, Indian, Bear, and Cortina, with lengths of from 10 to 30 miles and widths of from 2 to 5 miles. Their soils, largely red and gravelly loams, are partly under cultivation. In the southern part of Colusa county the region flattens out, but in Yolo county it rises into a belt of low, rolling hills, which reach eastward to within 3 miles of the railroad and southward to Cache creek, and even beyond, to within a few miles of Woodland. Its width is about 4 miles, and its soils are mostly dark and gravelly, with tracts of red lands. Fairview valley, on the west, a "hollow" some 2 or 3 miles wide, separates it from the Coast range. On the south of Cache creek the foot-hills become a very narrow belt, reaching to and a little beyond Vacaville, Solano county, and embracing a region south of Putah creek known as the "Vacaville fruit belt". Southward still to Suisun bay there are but a few low, isolated hills to mark the termination of the belt.

The Vacaville fruit belt is about 12 miles long and from 1 to 3 miles wide, embracing Vacaville and Pleasant valleys and foot-hills, and is limited on the south by the Montezuma hills. These valleys open out into the Sacramento valley, and their soils are chiefly dark loams, with some adobe around the town of Vacaville. A portion of the region is in what is known as the thermal belt of the Coast range, lying a few hundred feet above the plains and above frost limits. The hills are partly timbered with scattered oaks, buckeye, etc., and where not too steep are, with the valleys, very largely under cultivation.

Soils of the foot-hills.

The following analyses have thus far been made of soils of the foot-hill region adjoining the great valley. While no systematic exploration of the region has made it possible to select the samples advisedly and systematically, yet it is probable that the main features of the "red soils" are represented within the list:

No. 559. *Red loam soil* from near Redding station, Shasta county, collected by Mr. N. J. Willson, of the Central Pacific railroad. This is a moderately heavy red-clay loam, with some gravel and but little coarse sand, which probably is somewhat heavy in tillage unless when just in the right condition. No notes regarding this soil have reached me, but it is stated to be the representative soil of the region around Redding.

No. 705. *Red chaparral soil* from a few miles west of Anderson, Shasta county; sent by Mr. George A. Moore, of Anderson, who states that this land is covered with a dense thicket of chaparral (*Ceanothus*) and poison-oak, with some small oaks and other brush. Depth taken, 12 inches. This soil is of a deep orange-red tint, and is quite heavy and cloddy when dry. The lumps cannot be crushed with the finger, but soften readily with water, and then show a considerable amount of coarse sand to be present.

No. 706. *Subsoil* of the above, taken from 12 to 24 inches depth; similar in aspect to the soil, but more clayey and less tractable, the clods also softening when wet. Mr. Moore says that "about 4 feet from the surface there is such a compact mass of clay and gravel that water does not penetrate over 15 inches from the surface".

No. 499. *Red upland loam soil* from near Wheatland, Yuba county; a stiffish, glaringly orange-red loam, forming the soil of the undulating uplands and stretching from the foot-hills several miles into the valley, and but little above the general level of the latter. This soil tills easily when taken in the right moisture condition, but plows very cloddy when either too wet or too dry. It is chiefly given to pasture and wheat-growing, and yields from 15 to 20 and sometimes 25 bushels of fall or winter-sown grain in good years, and in poor ones from 11 to 13 bushels per acre, but never altogether fails. It responds very kindly to summer fallowing, and in its natural condition has little else than herbaceous vegetation, with some scattered poison-oak bushes.

No. 51. *Red surface soil* from the foot-hills near Auburn, Placer county, taken 12 inches deep; sent by Mr. N. S. Prosser, of Auburn. Original vegetation, oak (*Q. Douglasii*), pine, and chaparral. This is a fair sample of the red soil of the placer mines, which seems to contain a small amount of gold everywhere, and has been washed on the small scale ever since the first discovery of gold in California. It is of a dark orange color, rather light in tillage and pulverulent when dry, forming a very fine reddish dust of considerable repute. It contains throughout numerous fragments of slate, more or less decomposed, of all sizes, and is usually underlaid by the same or its *debris* at a variable depth, rarely less than several feet, unless lying on steep slopes.

No. 190. *Red loam soil* from the foot-hill slopes near Lagrange, Stanislaus county. Vegetation, scattered oak timber (mainly blue and white oaks), with little or no underbrush save some poison-oak; also grass and flowers. This is a moderately heavy, glaringly orange-red loam, tilling well unless when very wet, contains but little gravel, and is not much in cultivation, save in gardens in this neighborhood; makes fine vegetables and fruits. Sample taken to 12 inches depth.

No. 191. *Red foot-hills soil*, taken two miles north of Merced Falls, on the Lagrange road, Merced county; depth, 10 inches. This is a rather heavy brownish red-clay soil considerably mixed with gravel. The natural vegetation is grass and scattered "blue" oaks, chiefly pastured at present, but capable of producing from 15 to 20 bushels of wheat per acre in good seasons and with good tillage.

No. 196. *Red gravelly soil* from the rolling "hog-wallow" country about eleven miles north of Merced city, on the Hopeton road, Merced county. This represents a rolling tract of foot-hill country extending southwestward from near Merced Falls, and, gradually flattening out, terminating near the railroad between Atwater and Merced stations. The surface, even to the hilltops, is deeply scored into "hog-wallow" mounds, separated by a maze of little channels filled with gravel, and sometimes with cobble-stones. In low, undrained places of this tract lies the "dry bog" soil, of which No. 701, from Tulare county (see pages 27, 28), may be taken as representing the best class. Land like No. 196 is not at all cultivated at present; but on the flanks of the ridgy tract lie lands like those at Huffman's (see No. 193, pages 27, 28) where grain-culture is very successful. The country is treeless and free from underbrush.

Soils of the foot-hills region.

	SHASTA COUNTY.			YUBA COUNTY.	PLACER COUNTY.	STANISLAUS COUNTY.	MERCED COUNTY.	
	REDDING STATION.	NEAR ANDERSON.		NEAR WHEATLAND.	NEAR AUBURN.	NEAR LAGRANGE.	NEAR MERCED FALLS.	ELEVEN MILES NORTH OF MERCED.
	Red soil.	Red chaparral soil.	Red chaparral subsoil.	Red-loam soil.	Red foot-hills soil.	Red foot-hills soil.	Red foot-hills soil.	Hog-wallow soil.
	No. 559.	No. 705.	No. 706.	No. 499.	No. 51.	No. 190.	No. 191.	No. 196.
Insoluble matter	76.274 } 80.376	63.384 } 68.864	63.194 } 67.904	78.789 } 82.592	69.52	67.915 } 74.879	73.352 } 77.858	79.078 } 84.622
Soluble silica	4.102	5.480	4.710	3.803		6.964	4.506	5.544
Potash	0.500	0.417	0.467	0.249	0.38	0.352	0.375	0.208
Soda	0.041	0.052	0.044	0.035	0.07	0.126	0.125	0.111
Lime	0.104	0.288	0.327	1.021	0.96	1.544	0.351	0.394
Magnesia	0.403	0.207	0.350	0.471	1.09	0.720	0.840	0.361
Brown oxide of manganese	0.009	0.037	0.029	0.018	0.39	0.031	0.066	0.033
Peroxide of iron	6.686	7.705	6.263	5.811	12.42	7.879	6.964	3.903
Alumina	8.480	14.443	17.434	6.283	10.97	9.864	8.804	6.660
Phosphoric acid	0.036	0.047	0.064	0.043	0.16	0.091	0.067	0.053
Sulphuric acid	0.012	0.074	0.043	0.019	0.01	0.362	0.221	0.082
Water and organic matter	3.968	7.680	7.229	3.644	5.14	3.766	5.060	4.143
Total	100.615	99.814	100.154	100.186	101.11	99.614	100.731	100.570
Humus	....	1.420	....	0.460	1.14	0.715	0.712	0.758
Available inorganic	....	....	....	0.336	1.12	0.448	0.407	0.533
Hygroscopic moisture	5.049	9.998	10.749	4.810	....	5.421	6.114	4.967
absorbed at	15 C.°	15 C.°	15 C.°	15 C.°	15 C.°	15 C.°	15 C.°	15 C.°

The above analyses show that the soils of the foot-hills are more variable in their composition than would be inferred from the general similarity of their appearance, viz: a high orange-red tint, arising from the presence of from about 4 to over 12 per cent. of finely diffused iron oxide (ferric hydrate), and a texture varying from that of moderately heavy loam to a stiff clay, with more or less of rolled gravel, at times to such extent as to impede tillage, and occasionally so closely packed as to render cultivation unprofitable. Their capacity for absorbing moisture is in all cases fair and adequate, and in some cases high.

The supply of lime is hardly adequate for such heavy soils as in the case of those from Shasta county. In that from Redding lime is deficient, and should be supplied where thriftiness is desired, and the same would be advantageous in the Anderson soils. Farther south the lime percentage increases, being high in the region from Wheatland to the Tuolumne near Lagrange, but again comparatively low in the foot-hills and hog-wallow ridges of Merced county. The superior adaptation of that middle region to fruit, and especially to grape culture, is doubtless connected with this fact. The supply of potash is only moderate, and in some cases low for such heavy soils, as in Nos. 499 and 196. In the case of the soil from Redding, the higher potash supply offsets, in a measure, the deficiency in lime.

As to the supply of phosphates, it is on the average quite low, being deficient especially in the Redding soil, and likewise, considering its heaviness, in the Anderson soil. In the latter case the use of bone-meal, recommended by me to Mr. George A. Moore, has resulted in a surprising improvement of production, thus proving the correctness of the indication furnished by analysis. The soil in its natural state failed altogether to produce remunerative crops, scarcely giving back the seed sown—"about one and a half tons of hay on six acres, and potatoes at the rate of about one-tenth of the bulk planted", as stated by Mr. Moore. The use of lime would doubtless still further help the thriftiness of this soil.

From the small amount of humus shown in the analysis of the Wheatland soil it seems probable that the sample represents a subsoil rather than the arable soil itself, and it may be that in the latter the phosphates would show a higher percentage. In the sample analyzed the phosphates are deficient, but the productiveness would, for the time being, be maintained, in consequence of the presence of so much lime and the greater lightness of the soil. Before long, however, phosphate manures will be desirable in that region.

The soil from Auburn is altogether the best of the foot-hill soils thus far examined, having a large supply of phosphoric acid, with plenty of lime, a fair supply of potash, and a high percentage of humus. The analysis shows good reason for the high estimate in which this region is held for the production of fruits, grapes, etc. The soil from the Lagrange foot-hills is not quite equal to it, but still it is a high-grade soil. That from near Merced Falls, No. 191, ranks somewhat lower, being very gravelly and having a smaller supply of both lime and phosphates, while the soil of the "hog-wallow" ridge, No. 196, ranks still lower, on account of a deficiency in potash. To the southward, in Fresno and Tulare counties, lime is again on the increase, as is indicated by the character of the valley soils and the occurrence of limestone in the foot-hills themselves; but no analyses of soils from these southern foot-hills have as yet been made.

It is thus evident that there are considerable differences and alternations in the character and value of the foot-hill lands, and that, while the greater portion is probably of fair to high quality, especially for fruit culture, there are tracts requiring manures from the very outset. Such can doubtless be recognized by an attentive observer from their vegetation. But my own observations, as well as the reports thus far received, are not sufficiently extended to determine what are the characteristic plants of each.

In view of the great uniformity of these soils to a depth of 15 inches or more, and their usually somewhat stiff character, deep and thorough tillage is indicated as of especial importance in their cultivation.

Soils of the foot-hill valleys.—As even the apparently uniform red soil of the foot-hills varies not inconsiderably, the same must be true to even a greater extent as regards the individual valleys within the region traversing belts of widely varying rocks. While it is true that the rivers of the Sierras most frequently emerge from the hilly country through narrow gorges or cañons, yet not inconsiderable areas of valley lands exist among the foot-hills. The following analyses were made originally with a view to a comparison between the original soil of a valley and the slum, or "slickens", that has overrun the same; but they are equally interesting as showing the wide divergence of the soil of individual valleys from the general average, whether of the foot-hills or the great valley itself:

No. 67. *Mining slum soil*, sent by Mr. J. Taylor, of Mount Pleasant, near Chinese Camp, Tuolumne county, December 16, 1877. The soil is a fine, cinnamon-colored sediment, deposited from the washings of the hydraulic gold mines of Chinese Camp and Montezuma. Some of the lumps in the soil were very hard to pulverize, yet most of them yielded to pressure between the fingers.

No. 68. *Valley adobe soil*, sent by Mr. J. Taylor, of Mount Pleasant, December, 1877. This is a black, clayey soil, now underlying the "mining slum" soil (No. 67) at a depth of 2 feet, and was quite fertile.

Soils of the foot-hill valleys, Tuolumne county.

	Mining slum soil.	Valley adobe soil.
	No. 67.	No. 68.
Insoluble residué	72.98	56.61
Potash	0.19	0.19
Soda	0.21	0.14
Lime	1.19	0.68
Magnesia	2.32	13.74
Brown oxide of manganese	0.08	0.08
Ferric oxide	9.30	18.43
Alumina	10.55	
Phosphoric acid	0.08	0.07
Sulphuric acid	0.03	0.01
Organic matter and water	4.43	9.84
Total	101.36	99.79
Humus	0.42	1.614
Available inorganic	0.36	0.395

The slum material is rather poor in the two most important ingredients of plant-food, potash and phosphoric acid, and it will probably be somewhat refractory in tillage for some time. In humus and available plant-food it is as yet naturally poor, but its redeeming feature, the large percentage of lime, will enable it to overcome this objection after having been covered with vegetable growth for some time.

No. 68 is a very remarkable soil in more than one point of view. On the whole, it is not dissimilar to the "slum" soil that has overrun it, and as regards the essential ingredients of plant-food it is no richer than the latter, except as regards the humus, and, consequently, the nitrogen and proportion of available plant-food. For the time being it would produce better than the slum soil, but ultimately both would be about equally durable, while neither takes a high rank in that respect. The unique feature of the adobe in this case is the extraordinary amount of magnesia, in which it exceeds all cultivable soils that have come under my notice heretofore. Both soils are probably derived substantially from the same original source, but the magnesian rock-powder has, in the case of the adobe, been so far decomposed by atmospheric action as to render its base soluble in the acid used in the analysis, while in the slum soil most of the magnesia has doubtless remained in the insoluble part.

A comparison of this "slickens" sediment with those previously discussed (pages 27–29) shows that there must be a very great difference in the agricultural value of the sediments coming from different valleys; for if the general sediment of the Sacramento river is so rich, despite the incoming of such materials as the one last described, the slum coming from some of the valleys must be of extraordinary richness, and a benefit to any lands covered by it to any moderate extent, when unaccompanied by the floods of gravel that render the richest materials practically useless for the purpose of the husbandman.

The sediment No. 67 now covers the original soil, No. 68, to a depth at which the latter is practically out of reach of the roots of crops.

THE SOUTHERN REGION.

The territory embraced in this division includes portions of the counties of Los Angeles, San Diego, and San Bernardino; in all a little more than 15,000 square miles.

The region subdivides naturally into a division embracing the Los Angeles and San Bernardino plains, the chief agricultural portion of southern California, and a division embracing the rolling hills, mesas, and interspersed valleys of San Diego. Both divisions are bordered eastward by the high and rugged mountains of the Sierra Madre, San Bernardino, and San Jacinto ranges.

The prominent feature of the southern region is the San Bernardino range of mountains, which, rising suddenly on the east to an elevation of from 4,000 to 6,000 feet above the sea, separates the coast belt from the great desert. From its junction with the Sierra Nevada mountains, in Kern county, it trends southeastward, and presently divides into two prongs, the northerly one continuing nearly to the Colorado river and gradually falling in elevation, the other, the San Jacinto range, bending southward, and, with a diminished height, passing out of the state into Mexico. This high range is almost altogether treeless and uninhabitable, has a width varying from a few miles to as much as 30 or 40 miles, and forms an almost unbroken barrier, with but few passes, between the great desert on the east and the agricultural valleys of the coast region.

To the westward of the range the mountains decline in altitude toward the coast, and are interspersed with many small valleys and mesa lands and penetrated to a distance of 75 miles eastward from the coast by the broad agricultural region known as the Los Angeles and San Bernardino plains. The higher mountains, those that lie near the San Bernardino range, are partly timbered with oak, cedar, pine, and fir, while the lower ranges are mostly bare, their lower slopes and cañons being covered with a chaparral. This division is watered by numerous streams flowing westward into the ocean, mostly without any great length. Of these the San Gabriel and Santa Ana rivers, in the Los Angeles plain, and the San Jacinto and San Diego rivers, in San Diego county, are the largest.

LOS ANGELES AND SAN BERNARDINO PLAINS.

The large agricultural region reaching inland from the coast, and bounded on the north by the high Sierra Madre or San Bernardino mountain range, on the west by the Sierra Santa Monica and others, and on the east (apart from the San Bernardino valley) by the Santa Ana mountains, covers an area of nearly 2,000 square miles. Its extent along the coast is about 65 miles, though broken by some mesa lands and hills. Northward it reaches about 35 miles across a chain of low hills to the mountains, whence it extends eastward for 40 miles in a belt of from 5 to 20 miles in width, forming the San Bernardino valley, and westward into the San Fernando valley, its entire length east and west being about 90 miles. It is divided properly into several large valley regions: the *San Fernando valley* on the northwest, separated from the coast and Los Angeles plain by the Santa Monica mountains; the *Los Angeles plain* proper, reaching along the coast from the latter mountains southeastward and inland to the high ranges, and including the San Gabriel valley; and the *San Bernardino valley*, forming the eastern extension alluded to, and separated from the coast on the south by the Santa Ana range of mountains.

San Fernando valley.—This valley covers an area of about 200 square miles, and has a length of 16 and a width of 12 miles, becoming very narrow on the east, where it opens through a gap into the Los Angeles plain. It is watered by the Los Angeles river, other streams from the mountains disappearing before reaching far into the valley. The surface is rolling, and on the north of the river there is a heavy growth of brush and cactus, the soil being very sandy. Along the river there are alluvial loams, while the lands of the rest of the valley embrace sandy loams, heavy on the northwest and light on the south, with alfilerilla, clover, sage-brush, some tar-weed, etc. Very little of its lands are under cultivation, the chief crop being small grain, with a yield of 30 bushels per acre.

Los Angeles plains.—It is usual to divide the Los Angeles region into a lower or coast plain and an upper plain, the former embracing a belt of low and "moist" land elevated from 5 to 80 feet above the sea, interspersed with low sandy ridges, and reaching inland for 15 or 20 miles. The coast-line of the county presents a series of low bluffs, sandy beaches, plains, and valleys on each side of the prominent headland that separates Santa Monica and San Pedro bays. The seaward slope is covered with a low and dense growth of sumac. The surface of the country rises inland, and is mostly undulating northward to the hills, where it becomes more broken, with low ridges and mesa or table-lands. Along the northern border of the plains the Sierra Madre mountain range breaks off precipitously on the south to a smooth, sloping plateau from 1 to 5 miles wide, which extends for a considerable distance along the base of the mountains through Los Angeles and San Bernardino counties. This plateau has a slope of from 100 to 300 feet per mile, and is evidently composed of the detritus washed down from the steep mountain slopes. From the Los Angeles river to the line separating the two counties the soil of this plateau is generally composed of red loam, compact and deep, containing considerable clay and fine gravel, while farther east gray granitic sand, gravel, and bowlders are the leading characteristics. In Los Angeles county this plateau in many places breaks off nearly vertically to a lower bench, along the rim of which large springs burst forth; but in general it slopes directly to the interior valley, with no perceptible division separating it from the valley proper. The country is without timber growth, except some willow, cottonwood, and sycamore along the streams, and sumac on the plains. The region is greatly diversified in its agricultural features and lands, the several varieties of sandy, gravelly, and clayey loams, both dark and red in color, occurring in irregular tracts, large and small, and gradually passing one into the other. The mesa or table-lands are chiefly red clayey loams, more or less gravelly, and usually occur near the mountain ranges, as well as in large bodies west and southeast of Compton, nearer the coast; they are said to be excellent grain as well as fruit lands. Throughout the rest of the valley dark loams, usually reddish, predominate. These loams are sandy, gravelly, and sometimes rocky near the hills and upon the higher tracts, while in the lower portions they are usually heavy, and often pass into the true adobe, a large body of which lies in the La Puente valley west of Spadra.

One of the most prominent features is the coast plain or "alkali lands" region, which occupies the greater part of the southern coast of the county. According to the records in the state engineer's office, this region extends from a few miles south of Los Angeles south to the coast, and southeast along the shore nearly to San Diego county, with a width of from 6 to 8 miles. The surface is partly flat, partly rising into low sandy ridges, between which lie the valleys or swales of alkali lands proper. The soil is usually a mouse-colored or somewhat bluish fine loam, sparkling with small scales of mica; it has little vegetation beyond the "alkali grass" (*Brizopyrum*), and the low portions do not produce well unless special means are adopted to counteract the effects of the alkali. This lower plain is the corn-growing region of this part of the state, its moist lands needing no irrigation and producing large crops.

There are a number of other tracts of alkali land in the higher portions of the county, notably on the San Gabriel river, east of Los Angeles, and on the north of the Santa Ana mountains.

San Bernardino valley.—On the north is the San Bernardino range of mountains, having an altitude of from 5,000 to 7,000 feet; on the east a low range of clay hills, having for their summit the divide of the San Gorgonio pass; on the south a low range of clay and granite hills; and on the west a high mesa, forming the west bank of Lytle creek. The surface of the valley presents a gently undulating or level plain, gradually rising toward the hills from the Santa Ana river, and in places is studded with trees. The soil is a gray gravelly loam, rather stiff in the center of the valley, becoming more and more sandy as the hills are approached. That at Riverside and on other plateaus or mesas is red and clayey in character and of great depth. These lands are said to produce as much as 35 bushels of wheat per acre, and are pre-eminently adapted to fruit-growing.

THE SAN DIEGO REGION.

Until quite lately all but the coast of San Diego county was difficult of access and little known to the general public. No systematic or even somewhat full description of the interior region has thus far been given in any publication, and what follows is compiled from many sources and cursory statements not always agreeing with each other. The country south of the Los Angeles plains is, along the coast through San Diego county, rolling and somewhat broken, interspersed with mesa lands and valleys, and is almost entirely treeless, comparatively little of it being suitable for cultivation. Inland the surface becomes more and more broken and hilly for about 30 miles to the low mountain belt that, with an elevation of about 3,000 feet, lies to westward of the high San Jacinto range. This mountain division is about 40 miles in width, though varying very greatly, and is a continuation southward of the Santa Ana mountains. It contains extensive tracts of good farming lands in the valley-like table-lands that are inclosed between the main mountain ridges and is said to be the best agricultural portion of San Diego county. Wheat, barley, oranges, grapes, etc., are among the products. Along the San Diego river there are narrow valleys that are among the best farming tracts of the county. Of these Cajon valley is perhaps the most noted, and may be taken as a type of the others. It is about 20 miles east of the city of San Diego, and, as its name indicates, has the appearance of a great basin 6 miles long and 4 miles wide, walled in on every side by mountains, and reached with difficulty, from which the San Diego river escapes through a narrow cañon. The surface of this valley is comparatively level and treeless, except along the river, where there is a growth of cottonwood, sycamore, and willow. The soil is a sandy, gravelly loam, largely under cultivation.

A descriptive pamphlet issued by the San Diego chamber of commerce says of the county:

The following is the picture presented to nine-tenths of the visitors who approach this county by way of the coast: Hard, gravelly table-lands, either barren or clad with a dreary black brush; rolling hills of gravel, bristling with cactus and cobble-stones; stony slopes, scarred with gullies and washes; no trees, no streams, no springs; the general barrenness relieved only by a few choice little valleys and a few tracts of good table-land. Looking inland, the visitor sees only swell after swell of bare hills looming through a dreamy haze and terminating in a high range of dark blue mountains on the east. The farming land, however, lies scattered in a thousand shapes all over a tract about 100 miles long and 70 wide, the greater part miles away from the coast, and visible only after many days' travel. Beginning at a point along the southern line of the county some 25 or 30 miles from the coast, and running back to the crest of the mountains bordering the desert, thence north to Temecula, is a belt upon which the rainfall is nearly always double, often triple, that of the country along the lower coast. Along this belt lie Valle de las Viejas, Cuyamaca rancho, the Julean hills and valleys, the Santa Ysabel, Mesa Grande, Warner's rancho, Guejito, Bear valley, Pauma, Smith's mountain, and smaller valleys too numerous to mention, with some large tracts along its edge partaking somewhat of its general nature, such as the Santa Maria, San Bernardo, Rincon del Diablo, etc. Upon the main part of this belt crops are as absolute a certainty as in any part of the east, and though subject to many of the causes that shorten crops in the east, such as unfavorable weather for "stooling" or "filling", etc., they never suffer from drought. All through this section fruit is raised in perfection without a particle of irrigation. * * * The average altitude of this belt is about 3,000 feet, and it covers about one-third of the country west of the desert.

Near Temecula this belt divides, one branch running off toward the high mountains on the east, the other bending off to the west, leaving the great plains of Temecula and San Jacinto, with all their rich lands, subject to the general uncertainty of the rainfall of all southern California. These plains often have as heavy a rainfall as the above-mentioned belt, but, as about once in three years they fall short, they cannot be included within it. The eastern branch of this rain-belt runs into a country in which bare, rugged, and dreary hills are the general rule, though there are a few fine little spots, such as Oak Grove, Bladen, and Aguauga, and some large valleys like the Coahuila.

A section of this western rain-belt, embracing Fall Brook, the greater part of Santa Margarita and Santa Rosa, running all the way to the coast at Las Flores and Forster City, and really including within its limits the Vallecito de Temecula, Monserrate, and the whole San Luis River valley above Monserrate, along with Paimousa and mount Fairview, has less rain than the main belt, but in the driest years the precipitation has never fallen below 7½ inches.

Fully three-fourths of the arable land in the county is alluvial, either washed from the ancient streams or lakes or from the hills, and free from rock or clay immediately below the surface; and on three-fourths of the rest the rock or hard-pan is too far below the surface to do any injury. The adobe, or California clay soil, one of the richest and strongest in the world, but one that requires much water at just the right times, is here comparatively rare, most of the soil being alluvial and very loose.

Timber is abundant throughout the river bottoms and in the mountains, willow, cottonwood, and sycamore prevailing on the former.

Soils of the southern region.

The lands of the inland valleys and mesas are characterized mostly by soils containing a large amount of gravel and coarse sand of a brownish or reddish tint. They are commonly distinguished into lands of the first bench, or bottom lands of the streams; lands of the second bench, forming either at the present time or originally a system of terraces elevated from 15 to 25 feet above the bottom lands, and still readily irrigable from the headwaters of the streams; and, finally, the mesa lands, lying at higher elevations and with no definite relation to the present drainage system, and not ordinarily conveniently irrigable from the streams, but dependent upon sources of supply lying high up in the cañons. Of course these distinctions are not absolutely maintainable, the second benches and lower mesa lands passing into each other imperceptibly, especially on the upper portions of the streams, while again, in the lower portions of the same, the second bench lands often lie high enough to be classed as mesas. On the slopes of the mesa lands the soil of the latter and that of the bench lands are frequently commingled.

It is to be regretted that none of the important soils of the "cienegas" have as yet even reached the collection of the College of Agriculture. Of those of the coast, only a few samples from the swales impregnated with alkali have been received, and these have been examined in respect to alkali only, as hereafter noted. The reddish-gray soils of the San Bernardino valley are represented in the table of analyses on page 40 by the soil and subsoil from the neighborhood of Pomona.

No. 130. *Surface soil* of the second bench of the San Gabriel valley, Los Angeles county, taken from Alhambra ranch, near San Gabriel, December, 1877, by Mr. J. De Barth Shorb. "A fair sample of the heavier class of soils in the San Gabriel valley." Color, dun or brownish gray, showing at once a good deal of small gravel and coarse sand. This soil lies higher than that on which the older orange orchards of the valley are planted, but the tree seems to thrive equally well on it when given sufficient moisture.

Nos. 382 and 381. *Soil and subsoil* from Pomona colony, Los Angeles county; taken respectively to the depths of 12 inches and from 12 to 32 inches. The soil and subsoil scarcely differ in appearance, and are a reddish-gray, rather sandy loam, easily tilled; natural vegetation, alfilerilla, clover and malva (*M. borealis*), and some "rattleweed" (*Astragalus Menziesii*); produces about 25 bushels of wheat and 10 tons of alfalfa hay per acre when irrigated, and is well adapted to cereals and fruits.

No. 47. *Surface soil of mesa land,* such as forms the larger part of the arable land in the southern part of San Diego county. This analysis was taken by Mr. F. A. Kimball, of National ranch, San Diego county, who thus describes it:

> The change of tint from surface soil to subsoil occurs at depths varying from 11 to 25 inches, and the sample sent represents the average from widely separate places, but with the same kind of soil. The underlying subsoil varies in thickness from 2 to 10 feet or more, is very retentive, and is of a clayey nature.
>
> The orange, lemon, and olive seem better adapted to this "red mesa" soil than to the best valley soils of the San Diego, Sweetwater, Otay, or Tia Juana rivers, a larger growth and earlier fruiting being invariable on the mesa. All the northern fruits, except perhaps the cherry and plum, are produced on it in the greatest perfection, the flavor of the apple and peach exceeding any I have tasted in northern California or in the east.

The soil is of a light reddish-brown tint, rather coherent, and apparently somewhat heavier in working than soil No. 130, which it otherwise greatly resembles, containing, likewise, a considerable amount of visible gravel.

No. 506. *Bottom soil* from the Colorado river between El Rio and Yuma stations, San Diego county; a silty, pulverulent soil of a light buff tint, dry lumps but little coherent, changes color but little in wetting, but becomes slightly plastic, showing some clay to be present. Unchanged to the depth of several feet; samples taken to 12 inches depth. This soil bears a heavy growth of mesquite trees, in low places arrow-weed, and on the Arizona side a great deal of creosote plant (*Larrea Mexicana*). Cultivation has not as yet been attempted here, but has been very successful lower down.

Soils of the southern region.

	LOS ANGELES COUNTY.			SAN DIEGO COUNTY.	
	Soil of San Gabriel valley.	POMONA COLONY. Low mesa soil.	POMONA COLONY. Subsoil.	Soil of mesa land.	Bottom soil, Colorado river.
	No. 130.	No. 382.	No. 381.	No. 47.	No. 506.
Insoluble matter	81.12	72.519 } 77.640	75.304 } 79.176	86.21	58.574 } 63.901
Soluble silica		5.121	3.872		5.327
Potash	0.27	0.869	0.962	0.48	1.177
Soda	0.17	0.296	0.301	0.14	0.162
Lime	0.68	2.354	2.052	0.36	8.671
Magnesia	1.77	2.225	2.154	0.54	2.966
Brown oxide of manganese	0.10	0.039	0.043	0.10	0.025
Peroxide of iron	6.30	3.097	7.342	3.69	4.139
Alumina	6.79	5.974	5.835	5.12	8.370
Phosphoric acid	0.16	0.018	0.049	0.23	0.133
Sulphuric acid	0.07	0.022	0.020	0.03	0.145
Carbonic acid	......	......	......	......	7.818
Water and organic matter	3.07	2.550	2.546	2.60	3.344
Total	100.50	100.054	100.480	99.50	100.860
Humus	......	0.324	......	0.555	0.752
Available inorganic	......	0.263	......	1.430	1.151
Available phosphoric acid	......	......	......	......	0.133
Hygroscopic moisture	2.30	3.460	2.370	2.340	0.204
absorbed at	15 C.°	15 C.°	15 C.°	15 C.°	15 C.°

While the first bench or bottom lands were the first cultivated and rendered highly productive by irrigation, the second bench lands seem to be scarcely inferior to the former for fruit production, at least, when properly irrigated. No. 130 was selected as a representative soil of this kind. Its potash percentage is rather low, but it has a good supply of phosphoric acid and lime, and its easy tillage and great depth, offsetting its somewhat low retentiveness of moisture, render it a very desirable soil. It is to be regretted that no analyses of mesa soil from the Los Angeles region are as yet available for comparison.

The *Pomona soil* may, judging from the great similarity of appearance, be taken as representative of a large area of similar lands in the San Bernardino valley. The soil and subsoil are a good deal alike in composition.

Both have a large supply of potash and lime, as well as magnesia, and both are poor in phosphoric acid, the soil even being remarkably deficient, and the supply apparently increasing with the depth. The supply of humus is very small, and its increase seems to be among the first needs of the soil. It must not be forgotten, however, that the surface soil in these dry regions is really of less importance than the subsoil, in which the roots must remain in order to be secure from the drought and heat. Evidently such land, while capable of high yields at first, will soon need phosphate fertilizers for continued productiveness.

The *mesa soil* from San Diego is of excellent composition in all respects but that of being somewhat deficient in humus, a fault easily remedied in cultivation. It is richer in both potash and phosphoric acid than the Los Angeles soil, but its smaller proportion of lime detracts somewhat from its advantage over the other. Considering its great depth and its large supply of plant-food, it is certainly of high promise, and would amply repay any reasonable expense incurred in its irrigation. Where convenient, this soil, especially where it is of the heavier kind, would be benefited by a moderate application of lime or marl.

The soil of the Colorado river bottom is certainly a highly productive one, easily worked, and not liable in case of overflows to suffer from wet, being quite light, notwithstanding its large percentage of alumina shown by analysis. It is a highly calcareous soil, containing, as it does, over 16 per cent. of carbonate of lime, partly in concretions, but mostly in a finely pulverulent form. Its potash percentage is very high; yet there seems to be no trouble from alkali, as the soda percentage is quite small. Its supply of phosphoric acid is fair, though not large for a bottom soil; the humus percentage is likewise small for a lowland soil, yet adequate. It is therefore likely that whenever the water of the Colorado river shall be made available for irrigation these bottom lands will yield rich returns for cultivation. It is worthy of remark that in this case the whole percentage of phosphoric acid is extracted with the humus, showing that it is entirely in the available form.

Alkali soils of the Coast belt.—The level or gently undulating region lying adjacent to the coast, as before mentioned, possesses a dark-tinted loam soil, characterized by a large proportion of glistening mica scales. The higher portions of these lands are free from excess of soluble salts, but the lower lands or "swales" intervening, and running usually down to the sea-shore, show more or less "alkali", and will not grow some crops at all on that account. Three samples of soil of this character have been sent for examination, with the results given below:

Salty soil from the coast flat between Anaheim and the shore, sent by Mr. Charles D. Ellis, of Anaheim; said to be fairly representative of the above tract, which is flat, and appears to be underlaid by brackish water at a depth varying from 4 to 6 feet. In low spots it is often covered with a white crust, and seeds fail to germinate there. The soil is a dark-colored sandy and micaceous loam, with a well-marked saline taste. Qualitative analysis showed simply the ingredients of sea-water. There is therefore no antidote or remedy but those usually applied to coast marshes, and the term "alkali" is improperly applied in this case.

Alkali soil from near Corvallis, Los Angeles county, sent by Mr. S. G. Baker, secretary, on behalf of "New River Grange", December 6, 1876. This soil is reported as occurring in streaks over a considerable district. "Nothing seems to grow on it except salt grass. Common mallows and corn will vegetate on it, but not mature. Fruit trees rot at the roots, and willows at the bark. Beets seem to thrive when irrigated, but when not irrigated grow very small, though much sweeter than when irrigated. It appears to be the earliest of our soils to get dry. I have subsoiled it 2 feet deep with little benefit. * * * A small patch, highly manured with cow manure, has been greatly improved. Another small patch, coated 4 inches deep with sand, will grow good corn." Brackish water is found at the depth of 10 feet, and a plentiful supply of good artesian water at 450 feet. "In most cases the land lies well for drainage."

The soil as received is of a mouse color; a light, sandy loam, glistening with particles of mica (as seems to be very generally the case in that region). It yielded to water 1.62 per cent. of saline matter, which, in 100 parts, consisted of—

	Per cent.
Chloride of sodium (common salt)	22.37
Sulphate of sodium (Glauber's salt)	51.19
Carbonate of sodium (sal soda)	17.48
Sulphate of potassium	8.74
Phosphate of calcium (bone phosphate)	0.51
Total	100.29

The amount of soluble salts in this case is very high, but probably represents the worst of its kind, taken from near the surface. The neutralization of the sodic carbonate by means of gypsum would doubtless afford partial relief at once.

Alkali soil from Westminster colony, Los Angeles county, sent in April, 1877, by Mr. W. G. McPherson, as chairman of a committee on alkali soils appointed by Westminster grange. A dark gray, rather sandy soil, glistening with particles of mica scattered throughout the mass. The letter accompanying this sample makes the following statements in regard to it: "This soil is taken from Westminster, Los Angeles county, about 5 miles from the ocean, and near the center of a tract of about 30,000 acres now occupied by farmers; and there is no farm of forty acres but has some of this kind of soil, or something similar. * * * The sample sent is of medium strength, varying from it both weaker and stronger. * * * It is a little too strong for barley, but beets will grow on it under favorable circumstances. The subsoil is apparently the same, only growing looser (sandier) downward to the depth of from 4 to 10 feet, where tough blue clay is met with. Above this blue clay is permanent water (faintly brackish), and below it, at a depth varying from 60 to 200 feet, is a bountiful supply of pure artesian water. Now, if you can give us a remedy that will render this soil available, you will be conferring a benefit upon a large number of people."

The partial analysis of this soil resulted as follows:

Soluble salts in the soil, 0.54 per cent. These salts were composed, in 100 parts, of—

	Per cent.
Chloride of sodium (common salt)	10.57
Carbonate of sodium (sal soda)	61.48
Sulphate of potassium	20.62
Carbonate of potassium (saleratus)	6.50
Total	99.26

The high percentage of carbonate of soda in this alkali explains the energetic action of so small a percentage in the soil. It was recommended that a dressing of 900 pounds of land plaster per acre should be given before rains or irrigation. The following report is eloquent as to the results:

I took one-tenth of an acre of the same soil from which the sample came, irrigated it, then sowed 65 pounds of plaster, then plowed 6 inches deep and sowed 35 pounds more, then harrowed and planted with corn. Where the water stood on top of the ground there is a good stand of corn, although, being the lowest ground, it was the strongest in alkali; but where the land was only sub-irrigated not more than half of the corn came up. I replanted, and only half of that came up. The first planting is about a foot high and growing vigorously, and has a good color. I think the failure on the drier part was caused by there not being sufficient water to bring the alkali in contact with the gypsum. This crop subsequently ripened well; and since then much experience of the same character has been had. Of course the presence of water to enable the chemical reaction to occur is absolutely essential. The duration of the effect of a single application will, of course, vary under different circumstances, and especially according to the nearness of the water-table to the surface.

HYDROGRAPHY.—In view of the fact that the availability of the agricultural lands of the region is entirely dependent upon its topography and hydrography, a separate discussion of these, taken from the report of the state engineer for 1878–'79, is here introduced:

The higher interior mountain range is drained by three principal streams, which break through the Coast or Santa Ana range with independent outlets to the sea; *i. e.*, the Los Angeles, the San Gabriel, and the Santa Ana rivers. These are fed by numerous tributaries, which join them before reaching the Coast range, but in their further course to the sea they receive no important accessions to their volume. During the rainy season these streams and their tributaries are dangerous torrents, sweeping down from the mountains in which they rise in large volume and with great velocity, carrying a mass of bowlders and gravel far out into the valley. They subside as quickly as they rise, and during the summer would dwindle to nothing, but that their supply is maintained by springs which appear in their beds from hidden sources.

The Los Angeles river traverses the San Fernando valley, emerging through a gap terminating the Santa Monica range, to the city; below the city the river bed is broad, shallow, and sandy, and only upon rare occasions does the water find its way entirely through to the sea, but is absorbed by the thirsty sands. The streams that empty into the San Fernando valley from the Sierra Madre have a very rapid fall, and, on reaching the valley, spread out into broad washes, whose beds are composed of bowlders, gravel, and coarse sand. In flood they flow entirely across the valley to the Los Angeles river, but in summer the water barely emerges from the mountains and sinks from sight in the porous channels. The lands irrigated from this river are confined chiefly to the vicinity of Los Angeles city.

The water of San Gabriel river, except in flood, is seldom more than sufficient to fill the two irrigating ditches of the upper district, which head directly at the mouth of the cañon and divert all the available supply, leaving the broad rocky bed of the stream entirely dry for 10 or 12 miles, when the water begins to reappear in the channel a short distance below the bridge of the Southern Pacific railroad. At this point the river has two distinct and diverging channels from 1 to 5 miles apart, having independent outlets to the sea. In each of these channels there are numerous springs, the water rising at a number of points along their course, forced to the surface by the impervious substratum of clay underlying the whole valley at a depth of a few feet. From these springs is derived the supply for the elaborate system of ditches in the low San Gabriel valley.

The Santa Ana river emerges from the mountains through a wild and precipitous cañon over a bed of loose bowlders, in which the greater portion of its volume is lost before reaching the valley. A few miles lower down the water begins to rise, but is diverted by an irrigating ditch, leaving a dry bed for 4 miles to the mouth of Warm creek, where the river receives a fresh supply from the *cienegas* (*a*) of San Bernardino basin. Thence to the Coast range the bottom lands are saturated with a succession of *cienegas*, which drain into the river. Between the Coast range and the sea the river supplies water to several large canals which head near the hills, the river itself spreading out into a broad bed of quicksand over 1,000 feet wide.

The *cienegas* of these two valley regions are an important feature with reference to their system of irrigation. They often cover many acres of land each, and have a thin layer of peat or moss, sometimes several feet thick, over the bed of gravel. This peat prevents the free flow of its waters, and blind-drains and artesian wells have been resorted to in order to increase the supply of the latter.

The supply furnished by these springs is much more constant and reliable than that of the natural surface streams, and, at a time when irrigation is most needed, is probably greater than that from any other source. In the series of springs which appear along the rim of the plateau between Arroyo Seco and San Gabriel river, furnishing water for the irrigation of the far-famed orange groves and vineyards of the "San Gabriel fruit belt", there are no less than 18 distinct *cienegas* in a distance of 8 miles, each covering from 1 to 40 acres of ground and supplying water for irrigating from 20 to 400 acres each.

In the center of the city of Los Angeles, on each side of the river, on the lower bottoms, are *cienegas* which afford considerable water, the supply apparently coming in from other sources than the percolation from the stream. West of the city, at the foot of the low hills, next the sea-coast, there are large *cienegas* covering several hundred acres, from which issues Bellona creek. Near Pomona there is quite a large *cienega*, which supplies water for 440 acres; total volume, about 3 cubic feet per second. The *cienegas* of San Bernardino basin are the largest of any in the southern country, and furnish the greater portion of the summer supply of the Santa Ana river. The two principal ones are near the town of San Bernardino, and cover an area of over 300 acres each. Opposite Riverside, in the bottom lands of the river, are other large *cienegas*, adding from 25 to 30 cubic feet per second to the volume of the stream.

The streams and *cienegas* are so inseparable that it is impossible to estimate the duty done by each. In the coast valley there are many large *cienegas*, which, aside from those of Bellona creek and the San Gabriel river, are not used for irrigation.

Artesian wells.—The third great source of water supply for irrigation is derived from artesian wells. The greatest artesian belt in all southern California is that running through the coast valley of Los Angeles, having a length of 40 miles and a width, as at present explored, of from 2 to 12 miles, the total area being about 300 square miles. The rivers mentioned cross the belt on their way to the sea, and the fact that the wells having the strongest flow are adjacent to the channels of these streams seems to indicate that the water supplying these wells is that which has disappeared from the streams above and percolated between impervious substrata at an elevation sufficient to give the head or pressure by which it is forced again to the surface through the outlets furnished by the perforations. The depth of the wells is from 50 to 550 feet, the usual depth being from 150 to 200 feet. The number of wells in the belt is over 500, and the greatest discharge is about 1.7 cubic feet per second; some of them irrigate from 100 to 200 acres each, though a well that will irrigate 40 acres is considered a good one. It is found that as the number of wells is increased the flow of all is diminished, showing that the supply is comparatively limited. Some of the wells on the higher land have since gone dry or ceased to flow; others flow only in spring time. Another natural effect has

a Cienega is a Spanish term locally applied to a swampy or boggy ground caused by the rising of subterranean waters to the surface. The word *cienega* always implies a spring and the marsh or moist land surrounding it, for which it is almost exclusively used in this section of country.

been noticed in some parts, that, since the boring of so many wells, the level of the surface water in the adjacent country above has gradually lowered; some of the *cienegas* on higher levels have also diminished in their flow. Flowing wells have also been obtained in other localities north of Los Angeles, and in the upper San Gabriel valley as well as in the San Bernardino basin. The depth at Pomona is about 160 feet, and the temperature of the water is 67°, winter and summer alike, while that of other wells in this southern region is but 62° F. A singular fact in connection with the Pomona wells is that by capping or uncapping any one of them the flow of the others is increased or diminished with regular pulsation.

In the San Bernardino basin artesian wells are bored rather for domestic use and small garden irrigation than for general agricultural purposes. The area in which flowing wells have been obtained, as at present defined, is confined to about 30 square miles, within which are the large *cienegas* and sources of Warm creek.

The natural gate, outlet, or drainage of the valley is in its southernmost portion, where the Santa Ana river passes between two hills of limestone, or rather what was once apparently one hill, since cut through. At this point the "bed-rock" is near the surface, forming the valley of San Bernardino into a complete and large catchment basin for the water-shed of a very large area of country, the main channel of drainage being the Santa Ana river. The soil of the valley, as far as pierced by artesian borings, shows it to be mainly granitic in character, stratified by alternate layers of clay, evidently swept in from the country east and south. Borings to a depth of 150 and 200 feet frequently pierce a bed of vegetable mold, proving that the valley has been filled up by gradual erosion of the surrounding hills. The estimated number of wells is from 400 to 425, and their diameter from 2 to 8 inches, that of the greater number being 2 inches. The shallowest wells are 80 feet, the deepest flowing wells 380 feet, the average being about 160 feet. The deepest well in the valley is 410 feet, and has a diameter of 7 inches. Vegetable matter, consisting of decayed tule roots and pine wood, was brought up from the last 60 feet.

THE DESERT REGION.

The area included in the desert region is nearly 35,000 square miles, embracing the largest part of Inyo, the southeastern and northeastern corners of Kern and Los Angeles counties respectively, all of San Bernardino except the southwestern corner, and nearly all of the eastern half of San Diego county.

This desert, known as the Colorado desert or basin, reaches far eastward into Arizona. On the west it abuts against the foot of the high Sierras, and on the south against that of the San Bernardino range of mountains, both rising thousands of feet above it. The larger part of its surface, as a plateau skirting the foot of the mountains, lies at an elevation of 2,000 feet above the sea, and is comparatively level, though broken frequently by isolated short ranges and peaks rising a thousand feet or less above it. In its center there is a large area which is not more than 1,000 feet above the sea, and in Inyo county a still smaller region, known as Death's valley, sinks to some hundreds of feet below the sea. Coahuila valley, or that portion of the desert included between the two prongs of the mountain range on the south, is mostly below 1,000 feet in elevation, a large portion sinking below the sea, Dry lake, near Dos Palmas station, on the Southern Pacific railroad, being said to be some 500 feet below this level. There are scarcely any streams through the desert, except along its border, where they flow from the adjoining mountains and soon disappear in the sands. Mojave river, which gives its name to the northern desert region, is the largest stream, but after flowing from the San Bernardino mountains for a short distance out into the desert it suddenly disappears. The desert is described as a sandy barren waste, interspersed with salt lakes and alkali tracts, destitute of all timber growth except occasional tracts of yucca, small nut pines, and juniper. It is, especially on the south, subject to very frequent and severe sand-storms, which not only cover the lands of the region with deep and shifting deposits of sand, but often blow through the passes, and, with their lighter sands, greatly annoy the people of the agricultural valleys on the west side of the mountains.

A few miles southwest from Dos Palmas there is a broad valley, bounded by ranges of hills of hard-baked red clay, called the Chocolate and Coyote mountains; and in this valley is the dry bed of a lake 40 miles in circumference, which is nearly 60 feet below the level of the sea. This great basin is separated from the dry beds of a number of creeks which appear to have once been connected with it by a level plain about 5 miles wide. Nearly in the center of this plain there is a lake of boiling mud, about half a mile in length by about 500 yards in width. In this curious caldron the thick grayish mud is constantly in motion, hissing and bubbling, with jets of boiling water and clouds of sulphurous vapor and steam bursting through the tenacious mud and rising high in the air, with reports often heard a considerable distance. The whole district around the lake appears to be underlaid with this mud, as it trembles under foot and subterranean noises are heard in all directions. Hot springs and sulphur deposits are numerous for many miles around this lake.—*Natural Wealth of California.*

DEATH'S VALLEY.—The following is taken from Cronise's *Natural Wealth of California:*

This valley, according to observations made by a party of the United States boundary commission in 1861, is sunk 400 feet below the level of the sea, while but 70 miles west of it are clustered a number of the highest peaks of the Sierra Nevada, many of which are from 12,000 to 15,000 feet in height. For 45 miles in length and 15 miles in width along its center it is a salt marsh with a thin layer of soil covering an unknown depth of soft gray mud, a large portion of the basin being covered with an incrustation of salt and soda several inches thick. The surface is usually so soft that a man cannot travel over it in winter without difficulty, it being impossible for animals at any season to cross it. With the exception of a few clumps of worthless shrubs near its borders, this plain is destitute of even the slightest traces of vegetation. The valley is encircled by a barren sage plain from 3 to 6 miles wide, which, beginning at the base of the mountains that surround it on every side but the south, slopes gently to its margin. A few mesquite trees grow among the sands at the head. The heat of the valley is fearful during the summer, ranging from 110 to 140 degrees during the day. When there is no breeze through the long cañon the air becomes so oppressive that respiration is painful and difficult. At a point about 30 miles north of Death's valley the Amargosa river, a stream of small volume but great length, takes its rise, and, flowing southeast for more than 100 miles, makes a detour when far out on the Mojave desert, and, bending round to the northwest, runs in that direction about 40 miles, when, having reached the southern end of this arid plain, it finally disappears.

Soils of the Mojave desert.—Ascending the mountains from Kern valley near Bakersfield through the Tehachapi pass, we emerge upon the western part of Mojave desert, a plain-like basin surrounded by mountains and more or less traversed by rocky ridges. In crossing this basin by rail during the dry season the traveler is generally impressed with the idea of hopeless aridity, which is scarcely relieved by the only tree-growth visible from time to time, viz, the yucca (here commonly but erroneously named "cactus"), whose awkward branches, terminated by tufts of rigid, lance-shaped leaves, impart rather a weird aspect to the landscape, and seem as uninviting to the agricultural prospector as the clouds of dust and sand that whirl about the train. But while it is true that there are some portions of this region whose deep sand beds seem to consign it to the true "desert land" class, there are other and very extensive tracts, having a soil of considerable native fertility, whose powers only need the life-giving agency of water to transform the desert into luxuriant fields and gardens. That this is so has repeatedly been shown by actual experiment at points where water was available. This is not at present the case at the railroad station of Mojave; hence the quality of the soil has not been tested by actual trial, but its appearance indicates a substantial nature where it is not covered by sand drifts. It seems to be directly derived from the surrounding mountains, along the base of which such soils seem to form a kind of marginal bench.

No. 332. *Surface soil* of the Mojave desert, taken near Mojave station, Kern county, by N. J. Willson, of the Central Pacific railroad, to the depth of 12 inches. A moderately heavy, dun-colored loam, with little coarse sand, containing siliceous and other rock fragments; slightly effervescent with acid, somewhat "sticky" when wet, and its color little changed. It would evidently till quite readily, but no cultivation has been attempted thus far. The vegetation is sage-brush, creosote plant, and a little grass.

Soil from Mojave desert, Kern county.

	No. 332.	
Insoluble matter	70.965	75.964
Soluble silica	4.999	
Potash		0.928
Soda		0.078
Lime		1.787
Magnesia		1.782
Brown oxide of manganese		0.626
Peroxide of iron		5.478
Alumina		9.227
Phosphoric acid		0.056
Sulphuric acid		0.012
Carbonic acid		0.456
Water and organic matter		3.903
Total		99.697
Humus		0.283
Available inorganic		0.370
Hygroscopic moisture		10.759
absorbed at		15 C.°

The analysis of this soil shows clearly that it is not inferior in productive capacity to some of the soils of the great valley, which it greatly resembles, save in the scarcity of humus or vegetable matter. Its supply of lime and potash is high, while that of phosphoric acid is low, but not more so than in some very productive soils of the valley. The scarcity of humus is the defect which it would be most needful to remedy, and this probably is best remedied by turning in a crop of alfalfa, which there could be no difficulty in growing where irrigation is available. There are doubtless many tracts where even this defect does not exist, since they are covered with a dense growth of small shrubs, under which grasses flourish in good seasons, giving pasture to sheep. Irrigation is here the all-important question, since the natural rainfall of about four inches, sometimes reduced to one or two, cannot be relied upon for any purpose. Only a detailed survey, however, can determine the tracts having an arable soil as against those overrun by arid sand.

THE COAST RANGE REGION.

The country lying between the great valley and the sea-coast is, on the whole, a mountainous one, traversed by many more or less disconnected ranges, usually trending parallel to or at a small angle with the coast. From Mendocino county, inclusive, southward to the northern end of the San Bernardino range, few points or crests exceed the height of 4,000 feet, and most of the higher ranges remain between 3,000 and 3,500 feet. Many of these are very rugged and barren and largely treeless. Of the lower ranges up to 2,000 and even 2,500 feet many are rounded in outline, deeply covered with soil, and, in the moister portions of the region, susceptible of cultivation to their summits. These in most cases are at the present time occupied only as grazing grounds, the bulk of cultivated lands lying in the numerous valleys interspersed between the ranges and on the lower slopes.

THE BAY COUNTRY.—A somewhat detailed description can alone convey a good idea of the various sections of the Coast range; but there is one prominent feature requiring notice at the outset, viz, the break caused by the drainage outlets of the great valley, Suisun bay, Carquines straits, and the bays of San Pablo and San Francisco, with their final outlet through the "Golden Gate". This "bay region" constitutes a climatic as well as a hydrographic and a topographic feature; for, insignificant as the break formed by the Golden Gate may seem, it modifies profoundly the climate of the country lying adjacent and opposite to it, not only by the influence of its cool tide-water, but as well by the correspondingly cool lower air-currents sweeping through it almost throughout the season, and carrying with them both the temperature and the moisture of the ocean, both modified by the cold Alaskan current. In summer the river of fog, a mile wide and from 600 to 1,500 feet high, may be seen flowing in steadily through the Gate in the afternoon, first submerging the city of San Francisco, and then broadening and sending off branches right and left up and down the bay, and toward evening reaching the opposite shore, where the Contra Costa range forms a barrier for a time. Eventually this is surmounted, and finally the cloudy ocean may reach as far as Mount Diablo, where it dissolves before the dry air of the great valley. The direct influence of this current extends about 10 miles each way on the opposite shore, causing an exceptionally low summer temperature, which fails to ripen the grape and the fig. On the western shore of the bay the ranges of the immediate coast form a barrier not surmounted by a considerable proportion of the summer fogs, under the lee of which a warmer summer temperature prevails on the bay-shore slopes of the counties of San Mateo and Marin, as well as on both shores of the southern portion of San Francisco bay toward San José. The cold currents strike across San Pablo bay into the lower part of Napa and Sonoma valleys, but are chiefly deflected so as to form a steady and sometimes hard "blow" through the straits of Carquines, beyond which they enter the great valley and form, as before stated, the regular "up-valley" winds of that region.

The features of the immediate bay country are in many respects so peculiar that, although in the subdivisions according to rainfall (given on page 12) it is conjoined with a portion of the coast region lying northward and southward, continuity of description renders it desirable to consider the rest of the Coast range in divisions lying north and south of the bay country proper.

The western shores of the bays near San Francisco, and around San Pablo bay to Petaluma creek, are rather abrupt, with but little valley land lying back of it in the broken country, in which mount Tamalpais forms the highest point and falls off southward to the "north head" of the Golden Gate. Around the outlets of Petaluma, Sonoma, and Napa creeks there is a considerable tract of marsh or "tule" land, but Mare island and Carquines straits fall off into rocky precipices, and on the Contra Costa shore the railroad winds laboriously along the base of low but rugged escarpments until it reaches the lower end of San Pablo bay. Here, back of the bold promontory that narrows the passage into San Francisco bay, begins the sloping plain and in part the marsh belt that skirts the eastern bay shore from San Pablo to San José, forming, with the corresponding plain lying south of San Francisco on the western shore, an important and thickly populated agricultural region. Opposite San Francisco this slope is about 3 miles wide, falling about 300 feet from the foot of the Contra Costa hills. Southward it widens to 7 or 8 miles on either shore, a tide-marsh belt of varying width skirting the bay shore, and the two belts, finally uniting at the lower end of the bay, form the broad and fertile Santa Clara valley, so noted for its charming climate and the production of fruit and wines. Here the summer fogs, having to surmount the high coast mountains, are much diminished both in frequency and in coolness, and the vine, fig, and almond attain great perfection.

The soils of this bay coast are substantially of three kinds. Immediately along the shore lies a narrow strip of sandy land, sometimes sand drifts, which influence more or less the character of the adjacent marshes; most of the soils of the latter, however, are heavy, and when reclaimed are very productive. Inland of these lies a broad belt of black, calcareous, and very fertile adobe or prairie soil, somewhat refractory in tillage, which toward the foot of the hills often becomes yellow and relatively poor. This adobe belt is interrupted by the sediment lands of the streams flowing from the Coast range to the bay, which are generally light and often of considerable width, although few of these streams are now of much importance, but the frequent shifting of their channels in past times has increased the alluvial surface. These sediment lands, frequently, of course, passing gradually into the adobe proper, are noted for their productiveness, and furnish much of the market supplies of the two cities in fruits and vegetables, but are more especially noted for the high quality of brewing (Chevalier) barley produced on them. Sugar-beets likewise succeed well, but cotton fails to mature its bolls within reach of the coast fogs.

The range skirting the eastern shore, commonly known as the Contra Costa range, though traversed by some abrupt cañons, has largely rounded crests and summits and gentle slopes with deep and in part very productive soils, now largely used for grazing purposes only, but susceptible of cultivation to the top. Extensive plantations of eucalyptus trees are beginning to be made on this range, and succeed admirably. They originally had some redwood timber, and have now in the cañons and on the northern and eastern slopes not inconsiderable bodies of live oak (*Q. agrifolia*), madroña (*Arbutus Menziesii*), laurel (*Umbelularia Californica*), and buckeye (*Æsculus Californica*); on the banks of streams the Western alder (*Alnus incana*) and maple (*Acer macrophyllum*), the buckthorn (*Frangula Californica*), with more or less undergrowth of hazel, poison-oak, bramble, and others, and much eagle fern (*Pteris aquilina*).

Thermal belts.—Among the climatic peculiarities belonging more or less to the whole state, but more especially pronounced in the valleys opening toward the bay, is the occurrence of "thermal belts", or minor regions exempt to a remarkable degree from the severe frosts of winter, but more especially from the later ones of spring, which are so dangerous to fruit about the time of bloom. These usually occur between 100 and 800 feet above the valleys, varying of course with the trend and exposure to the coast winds. The difference in temperature at sunrise between these belts and the valleys sometimes amounts to as much as 10° F., which, in a region where the thermometer rarely falls below 26°, of course implies a very material difference in the chances of such fruits as almonds, apricots, and even the vine, and in many cases permits of the successful culture of semi-tropical fruits, such as the orange, lemon, pomegranate, etc. Thus the latter are successfully grown, *e. g.*, in certain valleys near Martinez, Contra Costa county, within 2 miles of the cold blast that sweeps through Carquines strait. Similar cases are frequent in the valleys of Napa and Sonoma, a striking example being that of the Vacaville fruit belt, in Solano county. In the Santa Clara valley the culture of the almond follows narrowly a similar warm belt.

COAST REGION SOUTH OF THE BAY COUNTRY.

That part of the coast region lying south of San Pablo bay to the southern region has an average width of about 60 miles, and covers an area of about 18,350 square miles. Lying between the coast and the great valley region on the east, it embraces within its limits the entire counties of Contra Costa, Alameda, San Francisco, San Mateo, Santa Clara, Santa Cruz, San Benito, Monterey, San Luis Obispo, Santa Barbara, and Ventura, and the western portions of Stanislaus, Merced, Fresno, Tulare, and Kern.

The surface of the entire region is mountainous and hilly, and is bordered on the east by a continuous range having an average elevation of about 3,000 feet above the sea, the highest probably of the region, reaching from Suisun bay southeastward through the state, and forming a long and rather wide barrier between the great valley on the east and the somewhat lower mountains and valleys of the central and western portions of the region. Westward from this range, which is often known as the Mount Diablo range, from the prominent peak of that name on the northern extremity, lie other mountain ranges of nearly or quite the same altitude, forming the appearance of long offshoots toward the northwest, each having a distinct name, and sinking on either side into the lower ranges before reaching the coast. The trend of the mountain ranges is thus usually northwest and southeast, and the courses of the rivers that drain the valleys between the mountains are northwestward into the ocean, except in the extreme south, in Santa Barbara and Ventura counties, where their course is mostly westward. These ranges are mostly destitute of trees, except scattered bodies of chaparral and sometimes other growth, and are partly too high and rocky for cultivation, being chiefly used for grazing purposes. The Contra Costa range, the first of the minor ranges (though not so high as the others) on the extreme north, abuts against the shore line of San Pablo bay, and, reaching southwestward, separates San Ramon and Livermore valleys from the "plain of Alameda", which borders the bay of San Francisco on the west. The range is broken by deep ravines and cañons, and is nearly treeless on the west and south slopes (except in the cañons, where there are clumps of oak, laurel, madrone, etc.), while on the east and north there is an abundance of live and white oaks, maple, etc. This range properly includes the higher Mount Diablo range on the east, with which it unites south of Livermore valley. Mount Diablo itself is an isolated peak, rising 3,896 feet above the sea, its summit rounded and its slopes nearly treeless, except in the ravines, where there is found a varied growth, with chaparral of scrubby oaks in the higher region.

The next ranges of note on the south are the Gavilan and the Santa Cruz ranges, apparently originally continuous, but now cut in two by the Pajaro river. The Gavilan range reaches northwestward from the southern part of San Benito county, separating that county from Monterey on the west, while the Santa Cruz range separates Santa Clara county from Santa Cruz and San Mateo. Both ranges rise to elevations of 3,000 feet, and are in part too high for any purpose except that of stock-raising. The Gavilan mountains are partly timbered with pine, except in the highest portions, which are rough, broken, and mostly destitute of trees. The Santa Cruz mountains are mostly heavily timbered with redwood and oaks, the redwood forest occupying a not inconsiderable area on the seaward side of the mountains, reaching in available masses as far north as Redwood City, many of the trees attaining a height of 200 feet or more. Scattered redwoods also originally dotted the ranges around and opposite San Francisco, but oaks alone now remain. On the east of the range is Santa Clara valley, and on the west are the Pajaro and the Salinas valleys, the most important as well as the largest of the region. Lying still further south is the Santa Lucia range of mountains, the most extensive of the offshoots, reaching from the main range, in the southeastern part of San Luis Obispo county, northwestward through Monterey to the coast. Its average width is about 30 miles, rising almost throughout its length into central elevations of 3,000 feet and more. The mountains are in places heavily timbered on their lower slopes and in the cañons with Monterey pine, cypress, and redwood.

Between this range and that bordering the San Joaquin valley are the high valley lands of the upper Salinas river and its tributaries, reaching northwest into Monterey county, and opening out through narrow defiles into the broad Salinas valley proper. On the west of the Santa Lucia range the high hills reach either abruptly to or within a short distance of the coast, the small streams usually accompanied with valleys of greater or less width. Still southward, at the junction of the Sierra Nevada mountains with the Coast range, we find a broad and extensive region of high mountains, the Sierra San Rafael, in the eastern part of Santa Barbara and northern part of Ventura counties, merging on the southeast into the San Bernardino range. The mountains are here cut into by the narrow Soledad pass (through which the Southern Pacific railroad has found a road-bed), which connects the Mojave desert with the cañons of the headwaters of the Santa Clara river, flowing westward to the ocean, the pass and the river valley thus forming a convenient east and west line of separation between the southern region and the Coast range division.

Near the coast, in the southern part of Santa Barbara county, and extending eastward from point Concepcion, there is a small but rugged range (the Sierra Santa Inez) from 2,000 to 3,000 feet in altitude, its trend nearly coinciding with that of the Sierra Nevada where it joins the Coast range.

THE COAST.—The coast line presents a very irregular contour, often deeply indented with bays, and throughout its length rises, usually quite abruptly, from the water's edge to elevations of 1,000 feet and more, the rocky prominences frequently projecting far out into the ocean. Its chief indentations are the bays of Monterey, Santa Monica, and San Pedro.

The general direction of the coast line is southeast in a direct line for a little more than 200 miles, thence southward for 100 miles to point Concepcion, the weather divide of the southern Coast region, where it suddenly strikes due eastward almost at right angles for more than 100 miles, finally rounding back to its southeast course to the limit of the state.

The rugged and hilly character of the coast is only occasionally relieved to any extent by level and tillable lands, except where the larger streams, especially the Salinas and the Santa Clara, have found their way to the ocean, producing broad areas of delta or alluvial land with the sediment brought down from the mountains.

The lands suitable for cultivation, and comprising, too, the only populous portions of the region, are the valleys that lie between the mountain ranges and skirt the streams, and also the foot-hills and lower ridges that are not too broken and rocky. From the coast these valleys rise in elevation and become more and more narrow to the cañons of the higher mountain ranges, through which their rivers have cut their way, and beyond which there are frequently other and higher mountain valleys of greater or smaller extent.

On the north of point Concepcion the river valleys have a trend southeastward from their outlet, while in the region of point Concepcion and southward the trend is eastward from the coast.

A description of the coast region is best given by taking the valleys consecutively. Beginning at the north, the first in order are—

SAN RAMON AND LIVERMORE VALLEYS.—San Ramon valley, lying between the Contra Costa range on the west and the Mount Diablo range on the east, opens northward into Suisun bay, and with a width of about 6 miles reaches south for 15 miles, where it becomes very narrow, finally opening out into the extensive Livermore basin or valley in Alameda county. The valley is dotted with scattered oaks, and its soil is largely a stiff adobe, in many places exceedingly black and waxy, which yields under cultivation about 30 bushels of wheat per acre. The soils around the base of Mount Diablo are partly reddish and partly gray, often gravelly loams. The valley is watered by streams flowing northward into the bay, and a number of small valleys connect with it on either side. Livermore valley, on the south, is about 14 miles long east and west, from 5 to 8 miles wide, and is surrounded by rolling foot-hills and mountains, from which other valleys open into it. The north and east part of its surface is a plain, the south and west part a region of rolling hills, and all is dotted over with oak trees and watered by numerous streams, timbered with sycamore, and tributary to Alameda creek, which flows westward into the bay of San Francisco through a cañon in the Coast range. The soil of the valley plain is dun-colored, with a pale yellow loam subsoil, often gravelly, more especially near the water-courses, the beds of which in summer appear filled with gravel only, although water is mostly found beneath. The soil of the rolling lands is mainly a red, often clayey loam, which also forms the subsoil where the surface soil is dark colored.

SANTA CLARA VALLEY.—This valley, with its adjoining foot-hills, is one of the most important agricultural districts within the limits of the Coast Range region. Its entire length is about 70 miles through Santa Clara into San Benito county, and its width at the bay of San Francisco, where it connects with the Alameda plain on the one side and that of San Mateo on the other, is about 20 miles. Eleven miles south of San José this valley suddenly narrows to about 100 yards, but again opens out to several miles until the Pajaro river is reached, whose valley westward is a connecting link with that of the Salinas river, in Monterey county. From the Pajaro southward for several miles beyond Hollister the width is about 12 miles, and the valley terminates or rises to a rolling plateau or bench land, which reaches across it, and is known as Poverty hill or Hollister valley. Still southward the valley region becomes more and more narrow and elevated, and is rarely over half a mile wide.

This Poverty Hill region is treeless, and its soil is an adobe, covered in the depressions of its surface with a silty loam, and underlaid at about 4 feet with a clay that is more or less alkaline in character. The lands between Hollister valley and the Pajaro river are partly adobe and partly a sandy loam.

In the broad valley north of this, in Santa Clara county, the surface is undulating, with low, rounded hills, and is dotted with clumps of oak. The land of the lower or northern portion near the bay is mostly black and stiff adobe, with some salt or marsh lands in the region of Alviso, near the bay. The higher lands of the valley are a lighter sandy loam, gravelly on the east and west, while those of the hills on either side are a cinnamon-colored loam, with a reddish-brown subsoil, well adapted to grape and fruit culture.

The area of the valley is almost all improved, and most of it is under cultivation. The crops comprise wheat, barley, corn, potatoes, and vegetables, and the yield of the black lands is said to be from 35 to 40 bushels of wheat per acre. Dairying is also carried on to a large extent. Grape and fruit-growing, including also figs, olives, and almonds, forms the prominent pursuit in the neighborhood of San José. The almond in particular succeeds in many favored localities of the "thermal belt" of the mountain sides that is protected from the direct impact of the coast winds and is sufficiently elevated above the valley to escape passing frosts.

The climate of the valley, as compared with that of San Francisco, is greatly tempered by the intervention of the Coast range between it and the sea, rendering summer fogs much less common, and thus permitting the ripening of many fruits that cannot be successfully grown nearer the Golden Gate. The same causes render the milder and warmer climate of the Santa Clara valley a health resort from the harsher atmosphere of San Francisco.

Cotton culture has not been fairly tested, but it is not, on the whole, likely to be successful so nearly within reach of the coast winds.

SALINAS VALLEY.—Reaching southeastward from Monterey bay for 90 miles, with a width of from 8 to 12 miles for the first 50 miles, is the Salinas valley. This valley is watered by the river of the same name, and inland becomes very narrow, rising rapidly in elevation to the mountain cañons in the southern part of the county, and through them connecting with the mountain valleys in the central part of San Luis Obispo county, in which the river takes its rise. The surface of the lower valley presents a terraced and almost treeless plain, the only growth being some live oaks on the northeast and sycamore along the river. The alluvial bottom lands are from one-fourth to one-half a mile wide, and are bordered by a somewhat higher terrace of adobe bottoms from 1 to 2½ miles in width. West of Salinas city there is a large tract of hog-wallow lands, embracing also a number of small tule lakes. The Salinas river flows mostly on the west side of the valley, a region of mesa lands lying between it and the Santa Lucia mountains still to the westward.

On the eastern side of the valley the adobe bottom lands are bordered by a sharply-defined terrace 11 feet higher, rising gently against the Gavilan mountain range. The surface of this terrace is rather rolling, and its soils are coarse, red, and gravelly, affording excellent farming lands where protected against the high winds that sweep in from the ocean every day during the year, and against which a person is said to be scarcely able to stand at times, the stock taking refuge in the thickets along the river. The valley is therefore chiefly used for stock-raising, very little farming being done. The higher connecting valleys on either side have mostly dark loam or adobe soils, and are partly under cultivation.

On the north, after passing a region of low, sandy, and treeless hills, the valley is connected with Santa Clara valley by the Pajaro valley, a heavy grain-growing region, which borders the river of the same name, reaching eastward from the coast. This valley is from 6 to 8 miles wide and its surface quite level, and embraces three varieties of soils: *dark loam lands* of the plains, adapted to wheat and barley; *adobe lands*, comprising one-third of the river bottoms, and lying several feet below the plains; *clayey loams* of the bottoms, known as the sugar-beet region. The valley is bounded on either side by a range of smoothly-rounded hills, those on the south being mostly too broken for cultivation. The small valleys between these hills are mostly swampy, with either tule or willow, and often hold small lakes or ponds of water.

The mountain valley region of San Luis Obispo county is watered by the Salinas river and other smaller streams, and presents a series of low, rolling hills, with intermediate valleys having separate names. The Salinas valley is, however, the chief one of this region, and is about 9 miles wide, with an elevation of about 1,000 feet above the sea. On the southeast it rises into a level plateau some 300 feet above the valley proper, and soon terminates; its lands are mostly adobe. There is but little timber. The bottom soil along the streams is chiefly a dark loam, while that of the upland or valley is mostly a stiff clay loam, usually reddish, more or less gravelly, easily tilled, and interspersed with some adobe tracts. This entire valley region is principally a stock range, though some of its lands are under cultivation. Paso Robles springs, a noted health resort, is situated in the northern part of the valley in a plain of about 10 square miles, and is surrounded by a grove of live oaks.

OTHER VALLEYS.—Along the coast in this county there is a series of valleys and plains which are separated from the immediate coast line by a chain of hills and watered by streams which are lined with cottonwood, sycamore, laurel, and live oaks. Their soils embrace the dark loams of the bottoms and the dark sandy or reddish loams of the valleys resting on heavy clays. The soil of the hills is lighter and gravelly.

Still southward the valleys of the Santa Maria and Santa Inez rivers are respectively about 10 and 2 miles wide and 30 long, each reaching the coast through narrow cañons, and having a greatest width about 15 miles inland. The Santa Inez valley was originally timbered with oaks. Its surface presents a series of terraces of 25, 45, and 95 feet, respectively, above the river.

The Coast region east of point Concepcion embraces two valleys or terraces, an upper and lower, varying in width from 2 to 6 miles. The immediate coast line forms at first a terrace about 80 feet high, sinking at Santa Barbara and eastward to the Ventura line to a lower level. The upper valley, known as the Santa Barbara plain, is about 300 feet above the sea. The soils of these coast valleys, both on the east and north of point Concepcion, are sandy loams, while those of the higher altitudes are largely adobe in character.

In Ventura county the Santa Clara and Buenaventura rivers are also bordered by narrow valleys, that of the latter river being about 30 miles long by about one-fourth of a mile wide and having sandy soils. The Santa Clara valley, which is sandy and very narrow from its source to Santa Paula, then widens gradually, until within 12 miles of the coast it suddenly expands into the Saticoy plain, widening to about 16 miles on reaching the coast, from the town of San Buenaventura on the north to that of Hueneme on the south. The northern portion of this fine agricultural region is largely an undulating upland with a yellowish loam soil; the southern constitutes a kind of delta of the Santa Clara river, its soil near the latter being a dark gray silty loam of great depth and fertility (see analysis below), remarkable for its retention of moisture near the surface, and noted for its high production of corn and beans, as well as its special adaptation, inland, to the European walnut. The mountain valleys have mostly adobe soils, and those whose altitude is less than 2,000 feet are partly under wheat culture. Of these the Ojai is the most important. Its lower portion has a dun-colored loam soil, timbered with white oak and very productive; but from this there is a sudden ascent of 500 feet or more to the upper valley, the soil of which is mostly a rich black adobe, producing enormous crops of wheat.

CHARACTER OF SOILS.—The characteristic reddish gravelly soils of the southern region extend to the sea-shore near Santa Monica and southward wherever there is a bluff bank, while where the surface descends more gently there are, as in the Westminster and Anaheim region, coast flats several miles in width, in which the soil is a dark-colored sandy loam, glistening with scales of mica, and more or less affected with alkali in the lower portions. Similar soils, in tracts of greater or less extent, are found up the coast as far as Santa Barbara at least. None of these soils have as yet been analyzed, except with respect to the alkali salts sometimes present in them, which at times are purely saline, at others strongly alkaline, from the presence of carbonate of soda. (See "Alkali soils of the southern region", page 41.) As a rule, these sea-shore lands are very productive.

The valleys of the seaward slope of the Coast range have mostly gray, light, and silty, rather than sandy soils, and are quite similar in appearance from Ventura to Humboldt county, though differing considerably in composition, those of the southern region being more calcareous, and apparently richer in phosphoric acid. Among the best agricultural valleys in this division is that of the Santa Clara river, in Ventura county, which opens out into the fertile plain of Saticoy. No soil samples from the latter have been received, but the following represent fairly the soil of the valley near Santa Paula:

No. 168. *Valley soil*, taken from Mr. N. B. Blanchard's orange orchard near Santa Paula, Ventura county. The color of this soil is a light umber, and when wet blackish and silty, very easily tilled, and retains its tilth remarkably, so that the hand can easily work its way into it up to the elbow and an ax-handle can be thrust down to the head with little exertion. The material remains apparently the same for from 12 to 20 feet in the lower bench of the valley, where this sample was taken. Toward the hills there is a second bench, where the soil is apparently the same, but of a slightly reddish tint. On the mountain slopes the soil, still quite similar in its working qualities, is of a decidedly reddish tint, and is remarkable for its retention of natural moisture, enabling it to produce corn without irrigation.

No. 182. *Reddish mountain soil* from Mr. N. B. Blanchard's land, near Santa Paula, taken to 12 inches depth.

No. 170. *Subsoil of second bench land* on Colonel W. Hollister's ranch, near Santa Barbara. (See page 50.) This specimen was examined, not as a fair sample of land, but with a view to detecting the cause of the dying-out of orchard trees some years after coming into bearing that occurs in streaks both here and elsewhere in the Santa Barbara region. The surface soil is dark gray or blackish, several feet in depth at most points, but where the dying-out occurs is underlaid by a whitish, sandy hard-pan, with pale rusty spots, indicating imperviousness and bad drainage. The spots are, however, known as having "poison soil", the trouble being ascribed to some injurious substance contained in it. The analysis shows no cause for any injury in the chemical composition of this subsoil, which is very fair in every respect, showing a high percentage of phosphoric acid, potash, and lime, and even, somewhat unexpectedly, of active humus. The cause of the difficulty is doubtless a mechanical one, the tree roots after a certain time reaching an impervious layer, waterlogging their roots in winter and leaving them unable to seek moisture in the depths of the soil in summer. Deep subsoiling, breaking up the hard-pan layer, seems to be the only possible remedy.

Soils of the Coast range south of the bay country.

	VENTURA COUNTY.		SANTA BARBARA COUNTY.
	Silty soil, lower bench, near Santa Paula.	Mountain soil (reddish), near Santa Paula.	Hillside subsoil ("poison soil"), Hollister's ranch.
	No. 168.	No. 182.	No. 170.
Insoluble matter	85.664 } 87.511	74.930 } 82.842	83.065 } 87.743
Soluble silica	1.847	7.912	4.678
Potash	0.634	0.621	0.506
Soda	0.070	0.164	0.058
Lime	0.759	0.952	0.561
Magnesia	0.593	0.955	0.666
Brown oxide of manganese	0.025	0.036	0.055
Peroxide of iron	3.350	5.070	3.116
Alumina	3.095	5.939	2.995
Phosphoric acid	0.260	0.127	0.223
Sulphuric acid	0.003	0.039	0.094
Water and organic matter	3.132	2.669	3.854
Total	99.372	99.414	99.871
Humus	0.841	1.055	1.341
Available inorganic	0.368	1.004	0.271
Available phosphoric acid	0.200	....	....
Hygroscopic moisture	5.488	6.590	5.980
absorbed at	15 C.°	15 C.°	15 C.°

Both soils from Ventura county show an excellent composition, the valley soil having the advantage of a high percentage of phosphates, while the mountain soil, a little heavier, with a smaller amount of phosphates, has a higher lime percentage and more humus. These soils are especially interesting, as being peculiarly favored in regard to their relations to moisture. No. 168 remains moist within from 15 to 20 inches of the surface during the driest part of the season, when the water table falls as low as 20 feet below the surface soils. The same is true more or less of the Saticoy plain at large; and the soil of other valleys, as, *e. g.*, the Ojai, is measurably similar. So are probably the valley soils of Santa Barbara, so far as I have had the opportunity of examination.

The first two of the following soils are from the Salinas Valley region:

No. 606. *Upland soil* from Poverty hill, San Benito county, collected by Mr. H. Partsch for the United States census; taken to the depth of 12 inches. This soil is of a dun color, somewhat silty, the dry lumps being easily crushed by fingers; softens readily in water, the color darkening but little; is easily tilled, apparently not adhesive, and produces moderate crops in good seasons, but is unthrifty and risky. This kind of land lies in the depressions of a kind of bench across the eastern head of the Santa Clara valley, while the higher portions are formed of a gray adobe, which also forms the subsoil of the loam lands at varying depths.

No. 600. *Loam upland soil* from Soquel ranch, Santa Cruz county, collected by Mr. H. Partsch. This is a reddish umber-colored loam when dry, the lumps crushing easily between the fingers, and softening quickly on wetting. It is very easily tilled, and contains some coarse sand. This sample represents the soils of the upland terrace which abuts upon the seashore southward of Santa Cruz.

No. 37. *Valley soil* from a small valley between Pescadero and Benton creek, about 200 feet above sea-level and two and a half miles away from the shore, sent by Pescadero grange, and selected by Messrs. Osgood, Burch, Weeks, and Thompson, committee. This soil is a brownish black loam, somewhat hard when dry, but softening easily on being wet, and taking almost a black tint; it produces good potatoes, barley, and oats. The product of potatoes has fallen, by cultivation, from 28,000 to 12,500 pounds; the cereals not so much. Deep tillage and thorough pulverization is found to be very beneficial in dry years. The timber in the valleys is redwood, oak, and alder, with buckeye, madrone, and pine on the uplands.

Valley lands of the Coast region.

	SAN BENITO COUNTY.	SANTA CRUZ COUNTY.	SAN MATEO COUNTY.
	Upland soil, "Poverty hill."	Loam upland soil, Soquel.	Valley soil near Pescadero.
	No. 606.	No. 600.	No. 37.
Insoluble matter	85.596 } 88.163	80.426 } 83.454	78.084 } 81.321
Soluble silica	2.567	3.028	3.237
Potash	0.333	0.343	0.541
Soda	0.109	0.126	0.231
Lime	0.676	0.502	0.925
Magnesia	0.526	0.390	0.820
Brown oxide of manganese	0.048	0.014	0.039
Peroxide of iron	2.856	3.928	4.934
Alumina	4.214	5.711	4.821
Phosphoric acid	0.027	0.053	0.084
Sulphuric acid	0.015	0.009	0.027
Water and organic matter	3.476	4.955	6.757
Total	100.443	99.485	100.500
Humus	0.819	1.463	2.850
Available inorganic	0.284	0.579	0.625
Hygroscopic moisture	5.218	5.602	7.387
absorbed at	12.5 C.°	15 C.°	15 C.°

Nos. 600 and 606, while still of the same general physical character as those of Ventura and Santa Barbara, differ chemically by their smaller percentage of potash and phosphoric acid, the latter being very decidedly deficient in the "Poverty Hill" soil. Their lime supply is still, however, quite adequate for thriftiness in such light soils, which, like those farther south, show a very satisfactory and remarkably uniform power for absorbing moisture, viz, from about 5½ to 6½ per cent. It is evident that here, as in the San Joaquin valley, the phosphates will be the first thing requiring replacement when these soils become "tired", and fruit rather than grain culture should be pursued by those cultivating them. It is not, of course, certain that these soils represent the character of the Salinas region correctly.

The valley soil (No. 37) from near Pescadero, San Mateo county, shows it to be of a somewhat higher grade than the above, and approaching more nearly in character the soils of Ventura, above described. It shows a high lime percentage, a large one of potash, and a considerably higher amount of phosphoric acid than the Santa Cruz soils, though yet rather low, being only half of that contained in the valley soils of Ventura and Santa Barbara. While sufficient for present thriftiness, in the presence of so much lime it is pretty certain to need phosphates so soon as its first fertility is exhausted, especially where dairying is the chief industry. The humus percentage is remarkably high for so light a soil within the coast region. It probably represents fairly the favorite soil of the redwood.

While on the seaward slope of the Santa Cruz range there is an evident predominance of light loam soils, the landward portion of that range seems to possess large tracts of heavy red-clay soils, whose character, of course, influences more or less that of the valley soils derived therefrom, especially in Santa Clara county. On the mountain slopes these lands are largely covered with "chaparral" (*Ceanothus*) and other scrub growth. The following is the analysis of a sample sent by Mr. William Pfeifer from a tract lying two miles northeast of Saratoga:

No. 702. *Chaparral soil* from Saratoga, Santa Clara county. Dark reddish brown when dry, forming hard lumps; dark umber color when wet, and softening easily; quite stiff in working, but assuming good tilth when taken at the right stage of moisture. Sample taken to the depth of 12 inches, below which lies a gravelly, rather stiff clay subsoil of an orange tint. More or less angular fragments of the country rock (a fine, soft, calcareous sandstone or shale) are contained in both.

Chaparral land, Santa Clara county.

	No. 702.	
Insoluble matter	57.449	62.563
Soluble silica	5.114	
Potash		0.859
Soda		0.260
Lime		1.987
Magnesia		2.428
Brown oxide of manganese		0.098
Peroxide of iron		10.019
Alumina		9.516
Phosphoric acid		0.139
Sulphuric acid		0.063
Water and organic matter		11.921
Total		99.853
Humus		3.096
Available inorganic		0.884
Hygroscopic moisture		12.090
absorbed at	15 C.°	

This analysis gives high testimony to the intrinsic value of the soil. It has an abundant supply of potash, as well as of lime, even for such a heavy soil. Its phosphoric acid percentage is fair, and its supply of humus is somewhat extraordinary for a soil formed in an "arid" climate. Its power for absorbing moisture is very high, from the concurrence of the large humus supply with that of iron oxide (ferric hydrate). It is therefore a soil of great resources, and is well deserving of the high culture which its peculiar mechanical condition necessitates. It must be kept thoroughly and deeply tilled, and its somewhat refractory subsoil should be broken up, so as to allow deep penetration to the roots. Not being irrigable, on account of its location, its best adaptation would seem to be to the growing of sweet grapes for the table, for raisins, or heavy wines. A very similar soil is found in some of the vineyards near Mission San José, and under high cultivation has yielded excellent results.

The soils of the San Francisco peninsula are derived from two distinct sources, viz, the disintegration of the country rocks and the sand drifting in from the seashore on the west. The latter originally covered the larger part of the present site of the city, and is still continually invading its rear, giving great trouble in and around Golden Gate park, where the efforts to subdue it have been measurably successful by the aid of grasses, shrubbery, and herbaceous plants adapted to the circumstances. Where the sand is excluded by protecting ridges the soil is mostly a somewhat stiffish one, formed from the clayey shales and sandstones, which are here and there replaced by serpentinous rocks. The latter influence the soils but little save as diluents.

The following analyses of soils from the Presidio reservation were made at the request of the United States military authorities, through Major W. A. Jones, of the engineer corps:

The *surface soil*, No. 680, is dark-tinted, varying in depth from 4 to 12 inches, according to location, and is moderately heavy. The *subsoil*, No. 682, is yellow and clayey, with a good deal of coarse sand, and contains abundant fragments of the soft, somewhat calcareous, sandstone from which it has been formed.

Sandstone land, Presidio, San Francisco.

	Soil.	Subsoil.
	No. 680.	No. 682
Insoluble matter	78.135 } 81.593	70.224 } 75.756
Soluble silica	3.458	5.532
Potash	0.675	0.590
Soda	0.080	0.172
Lime	0.846	0.399
Magnesia	0.780	1.221
Brown oxide of manganese	0.053	0.059
Peroxide of iron	5.682	7.268
Alumina	5.162	9.737
Phosphoric acid	0.031	0.011
Sulphuric acid	0.053	0.022
Water and organic matter	5.404	4.900
Total	100.359	100.135
Humus	2.284	
Available inorganic	1.045	
Hygroscopic moisture	6.028	9.411
absorbed at	15 C.°	

This soil shows a good supply of plant-food, with the exception of phosphoric acid, in which it is very deficient, its subsoil having scarcely more than what might be called a trace. Its high percentages of potash, lime, and humus make it an excellent subject for effectual improvement by the use of phosphate manures, which are manufactured in the city of San Francisco, but thus far have found little sale. The soil overlying the serpentines differs from these merely in a higher percentage of insoluble matter and magnesia.

The Mount Diablo range from San Pablo and Suisun bays to San José has mostly heavy "adobe" soils on its flanks and in the smaller valleys, as well as on its eastern foot, in the San Joaquin valley, and the heavy grain crops produced even to the very summits of the ridges in good seasons testify to the fertility of these somewhat refractory soils, whose productiveness varies sensibly in accordance with the amount of lime present in them; and this, again, can in a measure be judged of by the more or less dark tint of the soil. Limited deposits of impure limestone occur with frequency among the clayey and siliceous shales of the range, in which calcite or carbonate of lime commonly fills the rock crevices. Where this is not the case, we occasionally have tracts of heavy clay soils of tawny tint, cold and refractory, and often ill-drained, with the siliceous, shaly bed-rock a few feet beneath the surface, and such, unfortunately, happens to be the character of a large part of the university experimental grounds, while in the valleys lies an excellent black adobe soil, derived from the higher portions of the range. The following analyses show the composition of these soils:

Nos. 1 and 2. *Black adobe soil and subsoil*, taken on the state university campus, Alameda county, in the rear of cottages 3 and 4, half way to the bridge. The black soil here is over 30 inches deep, underlaid by a yellow, stony subsoil. It becomes exceedingly "sticky" when wet, but plows easily when taken just at the right point of moisture; when plowed a little too wet it clods heavily, but the clods tend to pulverize in drying. With shallow tillage, or when left untilled, it forms widely gaping cracks in the dry season; but if tilled deeply and thoroughly it retains moisture and a luxuriant growth of weeds throughout the dry season, and is almost ashy in its tilth. The soil having been sown in grain, so far as known, for many years and worn badly, it was deemed best not to take the surface soil for analysis, but a layer from 12 to 22 inches depth, and then another from 22 to 30 inches, the latter representing the extreme probable range of crop roots. The results of the analyses of both of these layers are given in the table on page 54.

No. 4. *Ridge adobe subsoil*, taken from the crest of the ridge on the agricultural grounds of the university, in the orchard, from the depth of 10 to that of 20 inches. Tint, a tawny yellow; very heavy in working, difficult to till at all times, and remaining wet until late in the spring. At a depth varying from 2½ to 5 feet it gradually passes into "rotten" shaly clay sandstones, fragments of which are everywhere intermixed with the soil. The tract is ill-drained, even on the ridge, and is esteemed a poor soil.

No. 643. *Black waxy adobe soil* from the Colton ranch, at the foot of Mount Diablo, Contra Costa county. Very black when wet, grayish when dry; when wet, excessively adhesive, so as to cling in masses to wagon-wheels, requiring to be scraped off from time to time. Vegetation, scattering white-oak trees (*Q. lobata*) and sunflower (*Helianthus Californicus*), but little else.

Adobe soils.

	ALAMEDA COUNTY.			CONTRA COSTA COUNTY.
	AGRICULTURAL GROUNDS, BERKELEY.			COLTON RANCH.
	Black adobe.		Ridge adobe.	Black waxy adobe.
	Soil.	Subsoil.	Subsoil.	Soil.
	No. 1.	No. 2.	No. 4.	No. 643.
Insoluble residue Soluble silica	} 77.844	69.563	86.002	50.960 9.020 } 59.980
Potash	0.452	0.348	0.189	0.192
Soda	0.074	0.109	0.154	0.741
Lime	1.056	0.998	0.484	2.471
Magnesia	1.211	1.918	0.452	0.890
Brown oxide of manganese	0.078	0.093	0.038	0.065
Ferric oxide	4.075	7.208	4.013	11.090
Alumina	7.788	13.970	5.532	15.689
Phosphoric acid	0.231	0.116	0.057	0.057
Sulphuric acid	0.077	0.028	0.021	0.045
Organic matter and water	5.718	6.600	4.051	8.304
Total	99.198	100.946	100.993	99.524
Humus	1.750	....	....	1.500
Available phosphoric acid	....	....	....	0.036
Available inorganic	....	....	....	0.829
Hygroscopic moisture	7.36	....	....	13.510
absorbed at	15 C.°	....	....	15 C.°

The obvious similarity of the black adobe, Nos. 1 and 2, to the "black prairie" of Mississippi and Alabama is abundantly confirmed by these analyses. Both in mechanical and chemical composition the adobe is so nearly like the "white lime prairie" soil of Mississippi that the differences are scarcely greater than might be found in different localities in either region. The prominent features are the high percentages of clay and the finest sediments, the influence of which in rendering the soil heavy in working is offset by a large supply of lime and black humus. The supply of potash is fair, and that of phosphoric acid large, being one-third above that of the Mississippi prairie soils. This explains the fact that grain crops, so exhaustive of lime, have for a succession of years been grown on California soil without apparent diminution. The subsoil below twenty-two inches seems to decrease gradually in the supply of plant-food. The sample analyzed probably represents pretty correctly the black adobe soils of the Coast Range slope from San Pablo to Mission San José.

The differences in the mechanical (a) and the chemical composition of this ridge adobe as compared with that of the valley is sufficiently striking. It contains less than two-thirds the amount of clay, yet it is much heavier in working, owing to the small quantities of the finer sediments, which chiefly serve to break up the extreme tenacity of pure clay, that is but little disturbed by the large-sized grains. Then the soil contains less than half as much lime as the lowland adobe, less than half also of the primarily important ingredients, potash and phosphoric acid, and, finally, a mere trace of vegetable matter, or humus, as is shown both by its tint and by the smallness of the "organic matter and water" item.

The unproductiveness of this soil is clearly owing to two causes combined. It is naturally poor in plant-food, and its mechanical composition makes it so refractory that it is only in exceptionally favorable seasons that what it does contain of plant-food can remain available to plants, since, in drying, it becomes of stony hardness, with only cracks to aid the circulation and penetration of air and roots.

This is one of the cases in which improvement by merely supplying the plant-food would be a waste of money unless the physical condition be corrected at the same time. Underdrainage would probably do this most effectually; green manuring would also be a very important aid; but the unusually small amount of clay for so heavy a soil promises excellent results from the use of a moderate quantity of quicklime or marl, and the fertilizer experiments made on the university grounds have fully sustained this inference.

Locally, we often find the heavier soils of the Coast range so modified by the admixture of gravel and sand derived from irregularly distributed geological deposits of this character as to render them easily tilled and specially adapted to the culture of barley and fruit. This is more or less the case along the streams on the borders of San

a See table of mechanical analyses on pages 83, 84.

Francisco bay, but especially so in Livermore valley, that remarkable basin inclosed between two branches of the Coast range, with apparently an ancient outlet through the San Ramon valley toward Suisun bay. Near Pleasanton the Coast Range hills are flanked and even capped by gravel conglomerates, which here, as well as farther up the "Arroyo del Valle", have largely contributed toward the formation of the valley soils, which are of remarkable depth and of easy tillage. The rolling land within the valley southwest of Livermore town has largely a red, stiffish loam soil, containing much small gravel; but at the lower points this red soil is overlaid by a dark-colored loam from 6 to 12 inches in depth.

Nos. 692, 693, and 694 in the following table represent this class of soils, and are from specimens furnished by Colonel George C. Edwards, of the University of California, the results of analysis being here given by his courtesy. The hill lands are scatteringly timbered with oaks.

No representative specimen of the valley soils has been analyzed, the following one being rather of a local aspect, yet giving some insight into the general character of the valley soils.

No. 649. *Sediment soil* from the "Ojo del Monte", a small valley just above the final exit of the "Arroyo del Valle" from the mountains, at the southeastern end of Livermore valley, Alameda county. This soil is a whitish, silty soil, with some tangible sand intermixed, easy of tillage, and of very uniform character to the depth of several feet. It is covered with a dense shrubby and herbaceous growth and some sycamore trees.

Lands of Livermore valley, Alameda county.

	ROLLING UPLANDS.			VALLEY.
	Dark soil.	Subsoil.	Red gravelly soil.	Soil.
	No. 692.	No. 693.	No. 694.	No. 649.
Insoluble matter	80.262 } 85.285	80.658 } 85.815	81.941 } 85.697	71.156 } 76.094
Soluble silica	5.023	5.157	3.756	4.938
Potash	0.299	0.357	0.323	1.143
Soda	0.108	0.121	0.081	0.123
Lime	0.818	0.693	0.720	2.049
Magnesia	0.647	0.666	0.563	3.046
Brown oxide of manganese	0.065	0.025	0.030	0.044
Peroxide of iron	3.584	3.047	3.620	5.648
Alumina	4.933	5.329	5.540	7.153
Phosphoric acid	0.066	0.062	0.061	0.117
Sulphuric acid	0.010	0.008	0.008	0.101
Carbonic acid	....	....	....	1.004
Water and organic matter	4.047	3.435	3.550	3.679
Total	99.857	100.158	100.193	100.201
Humus	....	....	....	0.396
Available inorganic	....	....	....	0.413
Hygroscopic moisture	5.670	6.120	4.580	5.668
absorbed at	15 C.°	15 C.°	15 C.°	15 C.°

These analyses show the difference between the upland and the valley soils to be very great, the latter being rich in potash, highly calcareous, and having a fair, though not large, supply of phosphoric acid; while the upland soils have, for California, an unusually low amount of potash, and a relatively still lower percentage of phosphoric acid. Still, with a fair supply of lime and considerable depth, when well tilled these soils promise well for the culture of the grape, now extensively begun in the region. Evidently, however, bone-meal or superphosphates will be among the first things needed here after some years' culture.

The soil of the level portion of the Livermore valley appears to be a mixture of the red soil of the hills with the valley deposits, and is noted as an excellent country for hay and cereals, though somewhat windy for fruit culture.

REGION NORTH OF THE BAY COUNTRY.

The division of the Coast range north of San Francisco and Suisun bays covers an area of about 20,750 square miles, embracing the following counties and parts of counties: All of Marin, Sonoma, Napa, Lake, Mendocino, Trinity, Humboldt, and Del Norte, and the western parts of Colusa, Tehama, and Siskiyou. The entire region is very generally mountainous, the eastern border being mostly a continuous range, with an altitude of 3,000 feet and more (above 4,000 feet in the western part of Siskiyou county) as far south as the lower edge of Lake county, and thence to the bay falling to the lower hills to less than 2,000 feet, the higher range, however, passing on the west side of Lake and Napa counties to within a few miles of the bay. From the high border region of the east, which in places has a width of 25 miles and more, other ranges of like altitude reach northwestward nearly to the coast, fully one-third of the entire region lying chiefly in the central and northern parts, thus having an elevation of from 2,000 to 3,000 feet above the sea. The altitude of the rest of the ranges is from 1,000 to 2,000 feet, except a hilly belt of less elevation bordering the ocean, which varies in width from 1 mile in the northern part of Mendocino county to 5 miles or more on the south, and to as much as 25 miles in Humboldt county. Near the coast, opposite or north of the city of San Francisco, is the prominent range of mount Tamalpais, once a part of the Santa Cruz range, but now separated from it by the Golden Gate.

The coast line, while having a general northwesterly trend, is very irregular and broken, with many prominent projections and points, and is indented with numerous bays. Among the former cape Mendocino is the most westerly point in the United States, and is in the line of the southwest trend of the highest mountain ranges of the north in their curve around the great central valley region. Point Arenas and point Reyes form other notable projections. This division of the Coast range is well watered by many rivers, some of the largest of which, with their tributaries, drain belts of country more than 100 miles in length. From the bay northward to the central part of Mendocino county, except in Lake and Napa counties, where the largest streams, Putah, Cache, and Stony creeks, flow into the great valley southeastward, the drainage is either south or west to the ocean. Still northward of this Mendocino water-divide the waters flow northwestward. Russian river is the largest in the southern part of the region; with its headwaters in the central part of Mendocino, it at first flows southward for more than 50 miles, reckoned in a direct course, into Sonoma county, then turns suddenly westward to the coast. Clear lake, a large body of water, not clear, however, in Lake county, has an outlet through Cache creek, eastward through Yolo county, into the Sacramento river. In the region north of the Mendocino divide there are three large and long rivers, the Eel, Trinity, and Klamath. The *Eel*, with its headwaters near those of Russian river, flows northwest and empties into the ocean south of Humboldt bay. *Trinity river*, its two forks heading respectively in the northeast and southwest corners of Trinity county, the former flowing at first southwestward, also has a northwest course to its junction with *Klamath river*. This latter river, the longest of the three, rises on the extreme northeast, flows at first southwestward with a tortuous course into Humboldt county, a direct distance of more than 100 miles, where, after its junction with Trinity river, it turns abruptly and at right angles northwestward into the ocean. Many other streams of the region have also great lengths.

REDWOOD BELT.—The high mountain ranges in the eastern part of the region are almost altogether treeless, except along their lower slopes, which often have a chaparral and oak growth. A prominent feature of the western part is a broad and irregular belt of redwood timber, which reaches uninterruptedly from the northern limit of the state southward a short distance beyond Russian river, in the southern part of Sonoma county, and scatteringly into Marin. In Del Norte county the belt is narrow, widening when it enters Humboldt county to 5 or more miles at first, and to its maximum of a little more than 25 miles in the southern part of that county, in the region of Eel river. Here, however, it becomes suddenly very narrow, 2 or 3 miles in width, and continues so for some distance into Mendocino county, when it again widens to an average width of 10 miles, which width it preserves to Russian river. This belt covers an area of about 2,400 square miles. A southern outlier occurs in Santa Cruz and San Mateo counties, and is mentioned in connection with that region.

The redwood belt is at present the most important timber region of the state, redwood being one of the chief varieties of lumber used in construction. Much of the belt is as yet difficult of access. The soil is in general very productive and moister than that of the adjacent country, but on account of the expense in clearing it is available chiefly where the lumber can be marketed.

AGRICULTURAL FEATURES.—The chief agricultural portion of the northern coast region lies within the counties of Napa and Sonoma and a portion of Lake. Northward of Sonoma county the narrow valleys along the larger rivers form the bulk of the cultivable land. This country is thinly settled, and lumbering and stock-raising, with some mining, are the predominant industries. The valleys are mostly covered with alluvial loams, and are only timbered along the bottoms with a growth of willow, cottonwood, maple, etc. Some of the land of Eel river is very black, and, with its growth of tussock grass, has received the name of "nigger-head soil". Around Ferndale and Mattole there is much eagle fern, which often attains a height of 12 feet. On both the Eel and other rivers northward the tillable land occurs only in small tracts. Around Humboldt bay there is much overflowed or swamp land, bordered on the east by hills containing sandy loam soils, and separated from the coast line by low sand hills having a stunted growth of trees.

The basin of the Klamath is very rugged, particularly that part of it within 40 miles of the ocean. Along the main river there is no valley or bottom land; its whole length is between steep hills and mountains, and through rocky cañons. Its largest tributaries, the Trinity and Salmon, run through a country almost as rugged as that bordering the main stream. Scott and Shasta rivers, which are the only other notable tributaries of the Klamath, have valleys of bottom land about 5 miles wide and 40 long.—*Natural Wealth of California.*

The valley of Russian river, in southern Mendocino and northern Sonoma counties, is narrow, has a sandy loam soil, and for 15 miles from its mouth had originally a timber growth of redwood, but now has only scattered groves of oak. Its lands are alluvial loams, rich and productive under cultivation.

Passing through Sonoma county, and continuous with the southeast course of Russian river, there is a series of valleys reaching to the bay and varying in width from 6 miles in Santa Rosa valley to 3 miles in Petaluma valley, bordered by a range of low mountains on the west and a higher range on the east. Sonoma valley proper leaves this central valley near Santa Rosa, and reaches southeastward to the bay, with a width of about 2 miles, widening to 6 miles near the bay. That of Napa, separated from it by the Sonoma mountain range, heads near the extinct volcano of Saint Helena, and extends southward 35 miles, with varying width, to the bay.

The soil of these valleys is a rich loam, usually gravelly, and very generally under cultivation, grapes and other fruits being now the prominent crops grown. Smaller valleys lie among the hills, which themselves are, to a large extent, susceptible of cultivation. The country rock is mostly volcanic, largely a soft tufaceous material, tending to form plateau ridges from 1,000 to 2,000 feet above the valleys. These ridges, as well as the slopes of the higher ones, are often quite heavily timbered with a great variety of oaks, among which the black (*Q. Sonomensis* or *Kelloggii*), live (*Q. chrysolepis* and *Wislizeni*), and blue or rock oaks (*Q. Douglassii*) are found on the higher lands, together with Sabin's pine (*P. Sabiniana*) and spruces, and the beautiful madrone tree (*Arbutus Menziesii*), which also descends into the valleys, being there associated with the coast live-oak (*Q. agrifolia*) and white oak (*Q. lobata*), and form desirable agricultural grounds. Here also the Sonoma or black oak assumes its finest development, forming (as near Healdsburg) large spreading trees of the habit of the eastern Spanish oak (*Q. falcata*). Interspersed with the oak growth are tracts of land covered largely with unusually large shrubs, almost trees, of the manzanita (*Arctostaphylos pungens*), which can nowhere be found in greater perfection, its chestnut-brown, shining bark contrasting beautifully with its pale-green leaves and the gray bushes of the chaparral (*Ceanothus*). The densest tree-growth occupies chiefly the northern and eastern slopes, those with a southwest exposure especially becoming too dry and heated in summer. This forest growth, within easy reach of the cultivated lands, has doubtless had its influence in rendering the valleys of Napa, Sonoma, and Petaluma so attractive that at present few uncultivated spots are to be found within them. The vineyards especially are rapidly extending up the mountain slopes, one especial reason therefor being the exemption from spring frosts enjoyed by the several "thermal belts" already referred to.

Along the bay, in the southern part of the region, there is much salt marsh and tule land. Some of this land has been reclaimed and is under cultivation, "two or three years being ordinarily required after leveeing and ditching before it is ready for planting."

But few specimens of soils from the coast region lying northward of San Pablo bay have thus far been received, and hasty personal visits have given me only a very general idea of their character and distribution. Unlike the Mount Diablo range, the mountains of Napa and Sonoma are largely formed by rocks of eruptive or volcanic origin, and where these prevail the soils are naturally different from those of the Cretaceous and Tertiary region south of the bay. The high quality of the wines of the two counties just named has largely been ascribed to the volcanic origin of their soils. Much of the rock constituting the lower and more level portions of the ranges of Sonoma and Napa is a soft, mostly whitish or white tufa, into which cellars have been readily excavated, and which gives rise to a more or less heavy clay soil—white adobe in the valleys, a red and more or less gravelly soil on the ridges. These tufa plateaus alternate with belts and ridges—mostly the higher points—composed of darker tinted, harder, and crystalline or scoriaceous rocks, less easily decomposed than the tufa, and giving rise to soils of a lighter character, gray or whitish in the valleys, from the removal of the iron by leaching. Of course there are all kinds of transitions between these two extremes, and occasionally even a genuine black adobe will locally show the prevalence of the calcareous sedimentary rocks.

The two samples from Sonoma, of which the analyses are given below, represent, respectively, the lighter sediment soils of the Sonoma valley lying near the foot of the slope and the red soil of the mountain sides themselves.

No. 185. *Valley soil* from the lower portion of the vineyard of G. F. Hooper, lying within a hundred yards of Sonoma creek, Sonoma county, taken to the depth of 12 inches. This soil is a medium light loam soil of a reddish-buff tint when dry, but blackish when wet. The dry lumps crush readily between the fingers and soften quickly when wet, but show some plasticity, so that the soil cannot be worked when very wet. It has grown excellent Zinfandel grapes for a number of years, and was originally timbered with oaks and grape-vines.

No. 188. *Red mountain soil* from the higher portion of G. F. Hooper's land, now occupied by orange and chestnut trees, taken to 12 inches depth, and similar in appearance for 2 or 3 feet. This soil is a brownish-red loamy soil, containing rock fragments intermingled; but the color darkens somewhat in wetting, and the dry lumps can be crushed by the fingers, but soften slowly on wetting, and become only moderately plastic. The soil is quite light in tillage, and produces well, and is evidently especially adapted to fruit culture, favoring early fruiting as well as early maturity. The original growth is oaks, manzanita, and some "chaparral".

No. 672. *Napa valley soil* from the vineyard of J. H. Wheeler, 2 miles south of Saint Helena, Napa county; a grayish sediment soil, with some coarser sand in the subsoil; taken to 12 inches depth. It is easily tilled, in low places tending to be heavy, and is much benefited by underdrainage. Then natural vegetation originally was oaks, grasses, etc. The soil has been under cultivation for some time.

Vineyard soils.

	Sonoma county.		Napa county.
	Sonoma valley soil.	Red mountain soil.	Napa valley soil.
	Hooper's vineyard.	Hooper's land.	South of Saint Helena.
	No. 185.	No. 188.	No. 672.
Insoluble matter	76.089 } 82.928	34.392 } 48.502	77.017 } 80.357
Soluble silica	6.839	14.110	3.340
Potash	0.435	0.319	0.746
Soda	0.123	0.058	0.477
Lime	0.744	0.670	0.600
Magnesia	0.578	0.712	1.331
Brown oxide of manganese	0.025	0.146	0.041
Peroxide of iron	5.793	25.955	5.656
Alumina	5.092	12.160	5.671
Phosphoric acid	0.187	0.166	0.101
Sulphuric acid	0.171	0.274	0.050
Water and organic matter	3.715	11.640	5.252
Total	99.791	100.602	100.282
Humus	1.111	2.537	1.685
Available inorganic	0.371	1.171	0.457
Hygroscopic moisture	4.980	13.710	4.503
absorbed at	15 C.°	15 C.°	15 C.°

While differing widely in their aspect and physical properties and in some points of their chemical composition, Nos. 185 and 188 are yet not very far apart in the most essential point—the supply of plant-food. In its percentages of potash, phosphoric acid, and lime the mountain soil stands somewhat below the valley soil; yet the supply of all three is fair. In humus the mountain soil exceeds that of the valley nearly one and a half times, and this, together with its extraordinary iron percentage, accounts for its very high power for absorbing moisture, and forms a very effective safeguard against injury from drought. On the whole, the advantages of the two soils are very evenly balanced, its location giving the valley soil a similar degree of security against drought; but it is evidently more liable to injury from frosts and wet than the hill soil. The latter, with its eastern exposure, seems certainly pre-eminently adapted to grape culture; and this adaptation is confirmed by the excellent results obtained in the vineyards of Köhler & Froehling, located on a similar soil higher up the valley, as well as in the well-known Schrammsberg vineyard, northwest of Saint Helena, in the Napa valley. I think it probable that, whenever quality shall be more evenly balanced against the mere quantity of production, the red mountain slopes of both valleys will be occupied by vineyards as high up as the vine will grow and produce the choicest wines of the region. In the Napa valley especially the vineyards are steadily advancing up the hillsides already, and on Howell plateau, at an elevation of 2,000 feet, they seem to promise excellent results. Here also we have a red, though somewhat heavier soil, timbered with a great variety of oaks and some nut pine, and it was on such soil that an excellent staple of cotton was grown in 1881 by Dr. H. Kimball, of Napa.

The Napa valley soil differs from the Sonoma soils in two chief points. It is considerably richer in potash, and, on the other hand, considerably lower in phosphates, as well as somewhat lower in lime. It may be that in both these respects the cultivation it has undergone exerts a depressing influence upon the results. At the same time, the abundant potash, no doubt, has some connection with the extraordinary crops sometimes grown in the Napa valley, amounting frequently to over 10 tons, and in a late and well-authenticated case to over 16 tons of grapes per acre. While such extraordinary production cannot be expected to yield first-class wines, yet its profitableness is beyond question.

No. 676. *Red volcanic soil* from a flat on Clear lake, Lake county, sent by Mr. S. B. Shaw, and stated to be representative of a large proportion of the cultivable land of the region; taken from a newly-planted vineyard to 12 inches depth. Below that depth the color is even higher and the soil more clayey; but between 2 and 3 feet it becomes of a lighter tint, and is less clayey.

The volcanic soil is of rather unusual composition and highly ferruginous, with an extraordinary amount of soluble alumina, which is not adequately represented in the shape of clay, as shown in the mechanical analysis given farther on, as well as in the small percentage of soluble silica. The supply of potash and lime is fair, yet not large for so clayey a soil. Phosphoric acid is very low, so that it is sure to be greatly needed after a few years' cultivation. Half of it, however, is shown to be in an available form by the humus determination. The supply of humus is ample, and moisture absorption high. Altogether, the soil is not one adapted to cereal culture, but will doubtless yield in that climate choice crops of fruit.

The only other soil sample from the northwestern part of the state thus far examined was sent by Mr. Waddington, of Ferndale, Humboldt county.

No. 207. *Soil of Eel river bottom* from three miles east of Ferndale, Humboldt county, taken to a depth of 12 inches. This is a gray silty soil, blackish when wet, and when worked in that condition somewhat adhesive and plastic, and very uniform for a long distance within the limits of the bottom. Original growth not reported. This soil produces excellent grain crops for four or five years, and continues to do so in favorable seasons; but after some years' cultivation it seems to "run together", so as to be difficult to till, and after late overflows especially becomes intractable for the season, so as to materially abridge crops. The analysis was requested with a view to determine how to obviate this trouble.

No. 205. *Subsoil* of the above, taken from 12 inches depth down to 25 inches. This subsoil is very similar in appearance to the soil, but slightly heavier, and is of lighter gray tint, with an occasional grain of bog ore.

Lands north of the bay country.

	LAKE COUNTY.	HUMBOLDT COUNTY.	
	Red volcanic.	Eel river bottom land.	
	Soil.	Soil.	Subsoil.
	No. 676.	No. 207.	No. 205.
Insoluble matter	49.604 } 55.538	65.346 } 72.242	69.373 } 72.961
Soluble silica	5.934	6.896	3.588
Potash	0.452	1.127	1.134
Soda	0.170	0.282	0.120
Lime	0.658	0.105	0.101
Magnesia	0.610	3.329	3.239
Brown oxide of manganese	0.051	0.117	0.054
Peroxide of iron	10.477	6.986	7.307
Alumina	22.585	10.286	9.758
Phosphoric acid	0.031	0.167	0.141
Sulphuric acid	0.033	0.020	0.026
Water and organic matter	9.654	5.629	4.665
Total	100.259	100.240	99.506
Humus	1.442	1.250	0.652
Available inorganic	0.393	0.590	0.427
Available phosphoric acid	0.014	....	....
Hygroscopic moisture	11.110	7.870	6.212
absorbed at	15 C.°	15 C.°	15 C.°

The analyses show the bottom soil to be one of great native resources—an unusually high percentage of potash and a very fair supply of phosphoric acid—there being a remarkable uniformity of composition through the entire soil-mass examined. The subsoil contains somewhat less phosphoric acid, and, of course, less humus; but in the surface soil the supply of both is ample. The one deficiency apparent in both is that of lime, the percentage of that important soil ingredient being smaller than in any other soil of the state thus far examined and unusually out of proportion to the other ingredients. This lack of lime accounts at once for a certain lack of thriftiness even in the virgin soil, and equally for the difficulty in tillage complained of. A few years' cultivation will still further reduce the small amount of lime in the surface soil and render it inadequate, not only for the maintenance of thriftiness, but also for that necessary condition of tilth, the "flocculation" of the clay. In the absence of a sufficiency of lime the clay assumes the "tamped" condition in which it is desired to be for the purposes of the potter, but not for those of the agriculturist; for it will then cause a clogging of the plow and the formation of hard lumps whenever the soil dries.

It is evident that liming is the first thing needful for those cultivating the Eel River valley soils, but whether lime or marl can be procured by them at a cost making its use practically possible I am not able to say. It is possible that limestone suitable for agricultural use exists in the region. In the meantime green manuring would help, in a measure, to obviate the difficulty, until better communication shall enable the farmers to use freely the obvious and best remedy on their otherwise so generous soil.

SIERRA NEVADA MOUNTAIN REGION.

The middle and northern portions of the eastern side of the state embrace the very high mountain chains known as the Sierra Nevada, which rise to elevations of 8,000 and 10,000 feet and more above the level of the sea, the elevation of some of the highest peaks being nearly 15,000 feet, forming a backbone-like though irregular chain in its center from north to south and dividing the region into what has been termed the eastern and western slopes. The former falls off rather steeply into a plateau region, which is elevated some 5,000 feet or more above the sea, and is the western limit of the Great American basin or desert. The western slope, known as the foot-hills of the Sierra, and to whose maximum elevation of 4,000 feet the Sierra proper usually falls off abruptly, reaches westward with a much gentler slope to the low valley lands of the Sacramento and San Joaquin rivers. This foot-hill region is, however, subdivided into an *upper or broken region*, which has an elevation of 2,000 feet and upward to the foot of the Sierra mountains, and properly belongs to that division, and a *lower region*, whose elevation is less than 2,000 feet, and which, being an important agricultural country, is separately described as the *foot-hill region*.

The Sierra Nevada ranges may be traced in consecutive order for an immense distance, the whole country for nearly 500 miles in length and nearly 100 miles in width—their extent within the limits of the state—being subordinate in configuration to two lines of culminating crests, which impart a peculiar character to its topography, while in the Coast range all is confusion and disorder.

The highest peaks of the Sierra Nevada, from mount Shasta on the north, including Lassen's butte, Spanish peak, Pilot peak, the Downieville buttes, Pyramid peak, Castle peak, mounts Dana, Lyell, Brewer, Tyndall, Whitney, and several others not yet named, which reach from 10,000 to 15,000 feet above the level of the sea, are nearly all in a line running north 31° west. On the eastern side of this culminating line of peaks is situated a series of lakes, the principal of which are Klamath, Pyramid, Mono, and Owen's, lying wholly to the east of the Sierra, and Tahoe, occupying an elevated valley at a point where the range separates into two summits. The confluence of the Gila and Colorado rivers forms the southern limit of the depression in which these lakes are located. A somewhat similar depression exists on the western slope of this ridge of high peaks, which is also about 50 miles wide, and is terminated by another series of peaks remarkably continuous in their direction and also containing a series of lakes. That section which lies to the east of the culminating peaks is generally termed the eastern slope. The depression on the west of this range and the subordinate range of peaks which bound this depression on the west is considered as the Sierra proper.—*Natural Wealth of California.*

The following are the elevations of some of the most prominent peaks, as determined by the United States surveys:

	Feet.
Mount Lyell	13,217
Mount Dana	13,227
Mount Brewer	13,886
Kaweah Peak	14,000
Mount Tyndall	14,386
Mount Shasta	14,442
Mount Whitney	14,898

The Sierra region, with its eastern and western slopes (omitting the lower foot-hills), embraces an area of a little more than 37,000 square miles. Uniting, as it does, with the Coast range of mountains on the north and south of the great valley, the line of separation between the two mountain regions becomes rather arbitrary. This is especially the case on the north, where mount Shasta and the valleys of the Sacramento and Shasta rivers, reaching from the great valley northward to the Oregon line, form a convenient line of separation, though the high mountain range, with a height characteristic only of the Sierra, extends much further southwestward toward cape Mendocino. Similarly on the south this high altitude belongs in part to the San Bernardino mountains, which trend with the Coast range and are included in the southern agricultural region.

The western limit of the region passes from the north, southward through the central part of Siskiyou county, into Shasta, thence extends in a very irregular southeast course to the southern part of Fresno, and turns southward to the southern part of Kern. The region includes the following counties and parts of counties, beginning on the north: The eastern parts of Siskiyou and Shasta; all of Modoc, Lassen, and Plumas; a small portion in the eastern parts of Tehama and Butte; nearly all of Sierra; the eastern parts of Nevada, Placer, El Dorado, Amador, Calaveras, Tuolumne, and Mariposa; all of Alpine and Mono; the western part of Inyo; the eastern halves of Fresno and Tulare, and the central portion of Kern, at whose lower line the region terminates almost in a point against the Coast range.

The prominent features of the Sierra region as thus outlined are: First, its somewhat central though irregular belts of high mountain ridges, their snow-capped summits towering thousands of feet above the rest of the region; second, a western slope of high and broken hills, mostly well timbered; third, an eastern slope, falling rapidly to an elevation of 5,000 feet, and interspersed with minor mountains, valleys, and great lakes, and on the north with large lava bed plateaus.

The high central range of mountains is a natural water-shed, throwing the drainage of the two slopes, respectively, east into the great basin in the state of Nevada and west into the Sacramento and San Joaquin rivers. An exception to this is Pitt river, which, rising in the northeastern part of the state, flows southwestward, cutting through a low portion of the Sierra chain and forming the chief tributary of the Sacramento river. The western slope is well watered by innumerable streams, large and small, the headwaters of nearly all of the large rivers of the great valley. The eastern slope contains very few streams of any size within this state. The mountains are usually timbered with pine, fir, cedar, etc. The entire Sierra region, as a whole, is sparsely inhabited, and its population is confined almost exclusively to mining towns, wood-cutter's camps, and a few railroad stations, and, if evenly distributed, would average but little more than one person per square mile. In some of the valleys on either side of the central range some farming and stock-raising is carried on, but mining is the chief pursuit of the people. In summer time large herds of stock, especially sheep, are driven to the mountain pastures from the plains.

THE BROKEN REGION OF THE WESTERN SLOPE.

The high and broken belt of country lying immediately at the foot of the high Sierra, and known as the higher or broken foot-hill region, has an altitude of from 2,000 to 4,000 feet above the sea; its width varies greatly, but is usually about 10 or 15 miles. In Plumas county this region spreads out to 35 or 40 miles, while in other places it narrows to not more than 5 miles. The rise from the lower foot-hills is often so gradual that the line of separation cannot be definitely marked out, while from the eastern border of this region the high Sierra mountains usually rise very suddenly to their great altitude. It is estimated that the region covers about 8,000 square miles. Of its topographical and agricultural features but little is generally known beyond the fact that it is throughout extremely broken with rugged hills and but few valleys, the streams mostly wending their way across the belt in deep chasms and cañons. The region is generally well timbered with oaks, pines, firs, and other growth, with big trees (*Sequoia gigantea*) in Calaveras and adjoining counties.

Lumbering and mining constitute the chief industries of the extremely sparse population, and the few settlements and towns found here and there are usually little else than camps, with a few necessary stores and trading posts. Little farming is done, as there is but a small portion of the entire region that is suitable for cultivation. In Plumas county, where the belt takes its greatest width of about 40 miles, there are a number of grassy and well-watered but treeless valleys, which stretch across the country for 100 miles in a southeastern direction, connected with each other by cañons, passes, or low divides, and have areas varying from 3 to 8 miles long and from 1 to 4 miles wide. These are Big Meadows, Butte, Indian, Genessee, Clover, and Sierra valleys, and are more fully described under the head of Plumas county, page 123.

The lands of these valleys are usually sandy, derived mostly from the metamorphic rocks that form high mountains on either side. The basin called American valley, in which the town of Quincy is situated, is about 11 miles long and from 2 to 3 miles wide, and has an elevation of 3,500 feet above the sea. This part of the region is principally occupied by the metamorphic rocks over an area of about 30 miles in diameter; but this is almost entirely surrounded by volcanic materials, the great lava streams which have come down from Lassen's peak on the north and Pilot peak on the south uniting with the volcanic crest of the Sierra, so as to cover the slates around three-quarters of the circumference of the circle. Between Indian and Big Meadows valley the edge of the great volcanic region is struck; from here the mass of lava extends almost uninterruptedly to the Oregon line and far beyond.—*Geological Survey of California.*

THE EASTERN SLOPE.

Nearly all of the region lying east of the Sierra chain is desolate in the extreme, and its surface is broken with mountains, ridges, and hills, and scarcely inhabited. Its southern part embraces large desert areas, its northern immense beds and table-lands of lava, while in its central part the state line approaches so near the Sierra chain as to leave very little of the slope within California. This region, even were its altitude lower than it is, affords very few facilities for profitable farming. Valley lands are found here and there, but these partake so much of the desert character of the southern part of the state, or are covered to such an extent by the volcanic materials throughout the region, as to be in many instances useless. We find, however, some large valleys that contain much good land that is at present partly under cultivation, and these are described separately. Excellent timber, comprising pine, fir, and cedar, covers many of the mountains, making lumbering one of the industries of the people. Cattle-raising is also largely engaged in, while in some of the counties, especially in the middle and southern portions of the region, mining is the chief occupation. The following descriptions are given of the chief valleys of the region, beginning on the south:

Owen's valley is a narrow basin between extremely lofty mountains. It is about 140 miles in length, north and south, and its average width is about 10 miles. Along its western edge it is bordered by the Sierra Nevada, which presents an almost unbroken wall in this part of its course, rising in its highest peaks, which are opposite Owen's lake, to 15,000 feet, and having no pass across it of less than 11,000 feet in elevation. Here the descent from the summit of the Sierra to the valley must average fully 1,000 feet per mile, and this would seem to be one of the steepest mountain profiles in the country. This portion of the Sierra as seen from the valley is peculiarly grand. The steep slopes rise from the desert plain and are everywhere naked and destitute of forests, the only trees being the pines in the cañons and the scattered nut-pines, which are scrubby and small, and extend up to about 8,000 or 9,000 feet, the rest of the ridges being made up of patches of bare soil, with exceedingly steep slopes of naked gray rock or snow. On the eastern side of the valley the mountains are more broken, but almost as high and grand as those on the western, and apparently forming a continuous range, called Inyo mountains on the south and White mountains farther north. The mountains are very dry and desert-like, not a single stream of any size flowing from them into Owen's valley, which is exclusively supplied with water by the melting of the snow stored away during the winter on the upper part of the eastern slope of the Sierra. The White and Inyo mountains are destitute of forest vegetation except a few scattering, scrubby pines, mostly the nut-pine (*Pinus Fremontiana*).

The tributaries which Owen's river receives from the Sierra are small streams. As they issue from the mountain cañons they flow out upon great piles of detritus or washes, consisting of coarse and fine *debris*, brought by the stream from the mountains and piled up on the plain with a gradual slope to the valley. This slope of detritus extends along the whole base of the mountains, but is highest where the streams come out, so that the latter often separate into several branches as they flow down it, thus making irrigation quite easy, and giving rise to a considerable expanse of meadow and cultivable land along the various channels. Lava beds extend from the mountains on the east and west, the two sometimes nearly meeting in the middle of the valley. In the region of Fish springs the lava bed on the west side of the valley is about 15 miles wide, and on the east about 10 miles. On the north lava occupies nearly the whole of the valley, and is highest along its center. Very little of the land of this valley is under cultivation, the tillable areas lying in small tracts, mostly in the southern half, in the region of Independence.—*Geological Survey of California.*

In Mono county there are two important valleys that are partly under cultivation, *Big Meadows* and *Antelope*, each about 10 miles long and very narrow. Their soils are mostly alluvial or of a dark soddy character, covered with grass, with some willow trees along the streams. The valley of *Honey lake*, in Lassen county, is about 60 miles long from east to west and from 15 to 20 miles wide. Its northern portion is dry and barren, and, with the exception of sage-brush and greasewood, is destitute of vegetation. On the west and southwest, near the Sierra, there is a strip of good farming land about 2 miles wide under cultivation. The soil of this part is a sandy loam, yielding with irrigation, which is necessary, from 25 to 30 bushels of wheat per acre. A number of other small valleys lying along the borders of small lakes in this region are chiefly devoted to grazing purposes. On the northwest of Lassen county *Big valley*, on Pitt river, covers a large region, embracing some good land, and is bordered on the east by long, oval hills and extensive table-lands, known as the Madaline plains. The surface of the valley is mostly covered with sage-brush; its soils vary from red clays to dark loam and gravelly lands, and are spotted with alkali tracts. The valley is chiefly devoted to stock-grazing.

The only other valleys worthy of mention are those that border the lakes in the northeastern part of the state, viz, Goose Lake valley and Surprise valley. The valley of *Goose lake* lies mostly on the eastern side of the lake, reaching back some 4 or 5 miles, and is watered by several small streams. Its lands are said to be good for farming purposes. They are covered with bunch and other grasses, and are partly under cultivation, yielding crops of wheat, barley, oats, etc. The adjoining mountains are heavily timbered with cedar and pine, while on the hillsides and around the lake is an abundant growth of wild plums. On the west side of the lake there is a narrow strip of valley devoted to dairying. *Surprise valley*, east of this, lies north and south along the state line for 60 miles, and has a width of about 15 miles. Three lakes lie within its basin, while on either side it is bounded by high and timbered mountains. Its surface is covered with grasses, and its soil is a rich black loam, occupying a strip from 2 to 6 miles in width, whose surface gently slopes to the lakes. The valley is settled in neighborhoods, and is partly under cultivation. Stock-raising and lumbering are carried on to a considerable extent.

THE LAVA-BED REGION.

A large proportion of the northeastern part of the state, from Feather river, in Butte and Plumas counties, northward to the state line, and from the Sacramento and Shasta valleys eastward to the eastern part of Modoc county, is covered to a depth of several hundred feet with great beds of lava and other volcanic material, and has generally a broken surface. The exact extent and outline of the region is not known, but it covers the eastern portions of Siskiyou, Shasta, and Tehama counties, the western part of Lassen county, the northwestern part of Plumas, and the greater part of Modoc. As determined by the state geological survey, the limit reaches on the southwest to within a few miles of Oroville, Butte county; thence northward its western limit reaches quite to the Sacramento river, near Antelope creek, in Tehama county, but recedes from it to the east beyond Battle creek, passing a little to the east of Fort Redding. The western edge of the great volcanic plateau may be traced in a line nearly northeast from that point for a distance of about 25 miles; it then bends to the northwest, and follows nearly that course to the north line of the state, passing a little to the east of Yreka, Siskiyou county.

The surface of this large region is much broken, and is interspersed with hills and high volcanic cones, frequently cut into deep chasms by the few streams that occur in the region. On the north extensive caves have been found under the lava-bed. Pluto's cave, 4 miles north of Hurd's ranch, in Shasta valley, Siskiyou county, is described as being under a lava table which slopes to the north, its surface very rough, raised into domes or blisters, and having a thin, dry soil. The cavern is a long gallery extending under this table, now open for about a mile in a northwest direction. Near the entrance the roof has fallen in several places; but otherwise the gallery is continuous, and has a width varying from 20 to 50 feet, the height being in some places as much as 60 feet. Throughout most of its extent the cavity is beautifully arched, having a section resembling that of an egg set up on its smaller end. The rock at the top and sides often has a concentric structure parallel with the sides of the arch. In places there are considerable quantities of spongy lava, which seems to have oozed from the sides in a frothy state. The whole appearance of the place is that of a cavity produced by the flowing out of the liquid lava after the sides and top had become consolidated. Excepting only the valleys mentioned above, the entire region covered by these beds is barren and desolate and almost without habitation, or lands that could be profitably tilled.

The lava-bed section at the northwest corner of Modoc county is a succession of gulches and crevasses which range from a few feet to 100 feet in width, and many of them are 100 feet deep; some have subterranean passages which lead for miles under the rocks. This broken country extends in a belt eastward to Goose lake.

This lava section of the country has no arable lands, and it is fit only for grazing purposes. It is a vast plain or table-land, and in some places it is sparsely covered with juniper.

Pitt river flows for 15 miles from Goose lake through a desolate plateau covered with large bowlders and masses of blackened lava, known as the Devil's garden, at the end of which it rushes, roaring and foaming, through a deep defile, named, from its wild and rugged aspect, "The Devil's cañon." Emerging from this gorge, it meanders quietly through Spring valley, so called because of a deep pool of hot water situated on its banks, which, agitated by the chemical action going on in its subterranean chambers, throws a volume of water as large as a hogshead to a height of 10 feet, which falls back into a large circular basin with the noise of a mountain cascade. The country adjacent to Pitt river, and with few exceptions the immediate valley of the stream itself, is for the most part an arid, barren, and timberless region. There is, however, some good land along the river in the southern part of the country, where also the juniper and cedar attain a size making them serviceable for fuel.—*Natural Wealth of California.*

Between Cow creek and Bear creek, Shasta county, there is a broad plain of volcanic ashes, destitute of trees, and almost bare of herbage, and as yet hardly at all eroded into cañons. On nearing Bear creek more solid lava makes its appearance and increases as we pass south. These volcanic materials are all derived from the great center of eruptive agencies at and near Lassen's butte. The examination of the region between that now extinct volcano and the Sacramento river shows that there were a large number of smaller volcanoes once active there, and that these added extensively to the mass of ejected materials. These consist of layers of ashes and scoriæ, alternating with hard basaltic lava, and they now cover a district about 100 miles long, from Pitt river south to Oroville, and nearly 75 miles wide. Between the mouth of Bear creek and Red bluff the volcanic rocks come entirely down to the river. They may be well studied at Battle creek, which rises at Lassen's butte, and has cut a deep cañon in the stratified lava, which is in places as much as 800 feet deep. The basaltic lava seems to have flowed in sheets over the surface, forming a regular slope from Lassen's butte to the Sacramento. All along Deer and Chico creeks, in Tehama and Butte counties, the lava terminates with an abrupt edge, and the plain beneath and nearest to it is barren and dry and covered with volcanic fragments; but farther down toward the river the land becomes gradually fertile, and has considerable timber. The proportion of good agricultural land increases as we approach Chico creek, where the plain is about 10 miles wide.—*Report Geological Survey of California.*

Southward from this great lava region the signs of a former volcanic activity in the high Sierra mountains are abundant, and we find as a prominent feature in many of the counties beds of basaltic lava capping some of the mountains, while on the western slope, and down into the lower foot-hills, there are still the remains of what were once heavy flows of lava from these mountains. In El Dorado county such can be traced through the central part of the county from east to west. In Amador the volcanic remains lie chiefly along the southern part of the county, "the great volcanic table or lava flow extending up the ridge between the Cosumnes and Mokelumne rivers." In Calaveras a belt reaches eastward from the northwestern part of the county to the north side of Cave city and the "big trees" and beyond.

The table mountain of Tuolumne county is a flow of lava originating in the lofty volcanic region beyond the "big trees" of Calaveras. It comes down on the north side of Stanislaus river, forming a nearly continuous ridge, elevated more than 2,000 feet above the river. Just below Abbey's ferry the river has broken through the once continuous basaltic ridge, which has been irregularly worn away for some distance from the river, but which reappears as a continuous mountain chain a little southwest of Columbia, and continues on the south side of the river, forming a conspicuous feature of the scenery as far as Knight's ferry, a distance of about 20 miles from the point where it crosses the river and enters the county. The surface of the mountain is very level, with hardly a trace of soil or vegetation.—*Geological Survey of California.*

South of Tuolumne county scarcely any volcanic accumulations have been found to show lava flows, though volcanic action is apparent in some of the mountains of the Sierra.

ALKALI SOILS AND IRRIGATION WATERS OF CALIFORNIA.

Alkali soils (*a*).—This name is applied in California almost indiscriminately to all soils containing an unusual amount of soluble mineral salts, whose presence is frequently made apparent by the "efflorescence", or blooming-out on the surface, of a white powder or crust, soluble in water. This "alkali" becomes most apparent in dry weather following upon rains or irrigation. Later in the season it usually becomes less perceptible from intermixture with dust, as well as from the failure of the soil-water to rise near enough to the surface. The first rain, dissolving the salty substances, carries them partly into the water-courses, but chiefly back into the soil, whence they rise again at the recurrence of dry weather.

The immediate source of the "alkali" is usually to be found in the soil-water, which, rising from below and evaporating at the surface, deposits there whatever of dissolved matters it may contain. Such water, when reached by digging, is by no means always perceptibly salty or alkaline, and the same is mostly true of the soil an inch or two beneath the surface; for since the soil, acting like a wick, draws up the soil-water and allows it to evaporate at the surface, it is *there*, of course, that all the dissolved matters accumulate, until the solution becomes so strong as to injure or kill all useful vegetation. The injury will usually be found to be most severe just at or near the crown of the root, where the stem emerges from the soil.

One obvious and practically important conclusion to be drawn from the above considerations is that the more water evaporates from the surface of the soil within a season the more alkali salts will be drawn to the surface. Hence, within certain limits, a greater rainfall will bring up a larger amount of alkali; or if, instead of rain, surface irrigation is made to supply an additional amount of water, the same effect will be produced; always provided that the rainfall or irrigation does not go so far as to actually wash a portion of the salts definitely beyond the reach of surface evaporation into lower strata, from which springs or seepage will carry them into the country drainage.

The measure of the rainfall or amount of irrigation water that will accomplish one or the other of these opposite results depends in a large measure upon the nature of the soil as well as of the underlying strata. It is more difficult to wash the soluble salts out of a clay soil than out of a sandy one, and the moisture and accompanying salts will keep rising through the former from greater depths and for a greater length of time after the cessation of rain or irrigation.

Roughly speaking, there is in California an obvious *inverse* relation between the rainfall and the prevalence of "alkali" in the soils. The concurrent increase of alkali and decrease of rainfall to southward is most obvious in the great valley, but is also observable more or less to seaward of the Coast range. The alkali question is of general importance chiefly in that part of the state lying southward of the city of Sacramento. In the region north of that latitude the more copious rainfall seems to keep soils leached of their alkali, if, indeed, it is naturally as abundant as in the San Joaquin valley.

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a So far as I am aware, no systematic investigation and discussion of this subject in its relations to agriculture has been made outside of the state of California, where the preponderance of the agricultural interest and the frequent interference of "alkali" with the extensive culture has forced public attention to the question, the more because of its intimate connection with the all-important subject of irrigation. I have therefore considered it best to present here somewhat in detail the experience and results obtained in the work done in California under my direction, published in the reports of the agricultural college of the University of California for the years 1877, 1879, and 1880, or subsequently elicited.—E. W. H.

Another conclusion resulting from the principles above mentioned is that in the practice of irrigation the nature of the water used is of great importance, since what it contains of soluble salts will be left in the soil by evaporation, helping to swell the mass of alkali year after year until it may become so great as to render the land unfit for cultivation; provided, again, that the amount of irrigation water used is not so great as to sink through into the strata supplying the country drainage, carrying with it its soluble ingredients also.

Effects of alkali.—While the corrosive action exerted by the alkali salts upon the root crowns and upper roots of plants is the most common source of injury, there is another source of injury which manifests itself mainly in the heavier class of soils thus afflicted, when the soluble salts consist largely of the carbonates of soda and potash. This is the great difficulty or almost impossibility of producing a condition of true tilth, in consequence of the now well-known tendency of alkaline solutions to maintain all true clay in the most impalpably divided or tamped condition, that of well-worked potter's clay, instead of the flocculent condition which it assumes in a well-tilled soil.

As this cause of injury is not so well known as the one first mentioned, it will be pertinent to adduce an example observed and studied in the neighborhood of Stockton, San Joaquin county, California, from where a belt of land of this character, about 1 mile wide and 14 miles in length, traverses the valley diagonally to the foot-hills of the Sierra.

This area is readily recognized by its pitted or "pock-marked" appearance, the low portions being impregnated with alkali and more or less incrusted with it on the surface during the dry season, while after rains pools of dark-tinted water remain standing on them for weeks after the higher portions are dry and in tillable condition. These higher portions, forming hillocks and ridges, elevated on an average from 10 to 18 inches above the alkali spots, and also bordering the whole tract, consist of a fine, mellow, loam soil, such as would be chosen for a garden, and very productive wherever the alkali does not influence it. Unfortunately, it lies so intimately interspersed with the alkali spots that it is practically impossible to cultivate one without the other. A short time before my visit the owner, Mr. C. L. Overhiser, had made a desperate attempt to conquer the refractory alkali soil. A mixed tract of the two soils had been plowed, cross-plowed, rolled, and harrowed until the harrow produced no further effect, and the result was a seed-bed of soil-clods ranging from the size of a pea to that of a billiard ball, but having no tilth. At the same time the portions of the "ridge" soil so treated were reduced to an ashy condition of tilth. Some of the alkali land had also been heavily manured, and a fair stand of grain was springing up, but Mr. Overhiser stated that, in accordance with previous experience, he expected to see the stalks "spindle up" and turn yellow about the time of going to ear, unless the weather continued unusually moist, so as to prevent the rise of the alkali to the root-crowns.

Inspection seemed to show that the two soils differ but little in mechanical composition, not nearly enough to account for such difference of tilling qualities; for when worked into a paste with water it was difficult to say which of the two was the heavier soil, and on drying from this condition both formed lumps about equally hard. For the final determination of this question the two kinds of soil were subjected to comparative mechanical analyses. Both subsoils are very much alike in appearance, being of a gray tint, very compact, and disposed to be cloddy. Both show an alkaline reaction on litmus paper (bluing the red paper), the subsoil of the alkaline spots being, however, decidedly the stronger. The mechanical analysis of the two surface soils resulted in showing that the difference in their proportions of clay and sandy ingredients of the several grades is so slight that under ordinary circumstances it would be insensible in tillage. The chemical examination of the soils resulted thus: The non-alkaline surface soil shows with blue litmus paper a faintly acid reaction (as is usually the case in cultivated soils). The alkaline surface soil shows a sharply alkaline reaction on litmus paper, and portions of it exhibit on the surface white needle-shaped crystals, apparently of carbonate of sodium. In the dead-furrows on the alkali tract stood puddles of dark-colored water, an analysis of whose solid contents is given below, alongside of that obtained by leaching the alkali soil in the laboratory, evaporating the coffee-colored lye, and burning off the vegetable matter. The total amount of residue obtained by the latter process amounted to a quarter of one per cent. of the dry soil. Of this amount 0.158 was again soluble, 0.093 remaining behind as earthy salts, etc. The soluble and insoluble parts were constituted thus:

SOLUBLE PARTS.			INSOLUBLE PARTS.	
Constituents.	Soil extract.	Dead-furrow puddles.	Constituents.	Dead-furrow puddles.
	Per cent.	*Per cent.*		*Per cent.*
Carbonate of soda	52.74	64.01	Carbonate of calcium	14.02
Chloride of sodium	33.08	13.06	Tri-calcic phosphate	5.37
Sulphate of soda	13.26	} 22.93	Tri-magnesic phosphate	5.77
Tri-sodic phosphate	1.83		Silica (soluble in Na_2CO_3)	24.37
	100.91	100.00	Iron oxide, alumina, and some clay (by difference)	50.47
				100.00

It will be observed that, notwithstanding the presence of considerable amounts of neutral sodium and calcium salts (which tend to render the soil more tillable), about 0.08 per cent. of carbonate of sodium was sufficient to render the soil practically untillable. Although this effect is much less perceptible in the case of soils containing less clay, it cannot fail to be, in many cases where it is not obvious, a determining cause in turning the balance of profit and loss the wrong way, especially in critical seasons. The change of carbonate of soda to some other form, at least, is therefore among the most important points to be gained in the reclamation of alkali lands; and fortunately this can be accomplished with little cost or difficulty by the application of gypsum or land plaster.

Another damaging effect of the alkaline carbonates upon the soil is the dissolution of their humus, which manifests itself in the dark color of the water standing on alkali spots and in the black rings left where such water evaporates, whence the popular name of "black alkali." When leached with water such soils will often appear almost white, and will remain unthrifty for some time until the humus is restored by vegetable decay. The application of gypsum prior to leaching, however, renders the humus insoluble again, and thus prevents its waste.

Reclamation of alkali lands.—The most obvious remedy for this evil is, of course, the leaching-out of the injurious salts by flooding, and, if possible, by underdraining. This method is habitually resorted to in sea-coast marshes, near the mouths of rivers, after the salt water has been excluded by embankments. The limited salty spots so frequently met with in the uplands of some regions are promptly cured by a few underdrains, through which the winter rains wash the salts definitely beyond the reach of the soil-water. Such spots are very commonly found extraordinarily fertile afterward. The problem of affording relief, however, becomes much more difficult when either a stratum of saline water or an earth-layer containing much saline matter lies a few feet beneath the surface in a level region, as is unfortunately very often the case in California. When this happens the evil can only be mitigated, but scarcely altogether cured. According to the value of the land to be reclaimed, one or several of the following remedies may then be employed:

1. When the "alkali" is not very abundant, or very noxious, *frequent and deep tillage* may afford all the relief needed. For inasmuch as the damage is in most cases the result of an excessive accumulation *at or near the surface*, it is clear that frequent intermixture of the surface layers with the deeper portions of the soil may so dilute the injurious salts as to render them powerless for harm.

Moreover, since a perfect tilth of the surface greatly diminishes evaporation, it tends to diminish, concurrently, the accumulation of the alkali near the surface. The same effect may be produced by mulching, or by covering the surface with sand.

With the aid of deep tillage it is often possible to raise on salty sea-shore lands root crops, such as beets or carrots, which absorb a large amount of soluble salts and sensibly relieve the soil, so that cereal crops may be grown the second or third year.

2. Underdrains may so far lower the water-table from which the saline matters are derived, and may so far favor the washing out of the salts during the rainy season, that the latter will thereafter fail to reach the surface so as to accumulate to an injurious extent with reasonably deep tillage. The roots of plants will go deeper for the requisite moisture, but will not be injured by the weak saline water below. With the aid of underdrains, in many cases a comparatively small amount of irrigation water may, when applied at the proper time, be made to produce the leaching effect upon the surface soil that would otherwise require a long time and a much larger quantity of water in order to wash the alkali into the country drainage.

3. When the quantity of the salt or alkali is small, but its nature such as to be nevertheless very injurious or corrosive, the evil may be greatly mitigated, or sometimes completely relieved, by the application to the soil of chemical antidotes, cheaply procurable in commerce. In order that the proper antidote may be chosen, it is of course necessary to determine the nature, and, in a measure, the amount, of the "alkali" by chemical analysis. The salts usually found in the California "alkali" soils, so far as they have come under my observation, are of three kinds:

a. Neutral alkaline salts, such as common salt, Glauber's salt, sulphate of potassium, etc. These are injurious only when present in large quantities, and relief can then be obtained only by washing them out of the soil by flooding, underdraining, etc.

b. Soluble earthy and metallic sulphates and chlorides, such as Epsom salt, bittern, chloride of calcium, alum, copperas, etc. The cheap and efficient antidote to these substances is lime; in some cases even a natural calcareous marl will answer the purpose.

c. Alkaline carbonates and borates. These, especially the former, are injurious in the smallest amounts, rendering the soil-water caustic and corrosive, and in clayey soils rendering it almost impossible to obtain good tilth, by their peculiar action upon the clay. They are most abundant in southern California, while the second and first class seem to prevail in the Sacramento valley.

The antidote to these, the true alkali salts, is gypsum or land-plaster. The efficacy of these antidotes depends, of course, upon the presence of water, without which they cannot act on the "alkali". They should be sown or spread on the surface and plowed or harrowed in to a moderate depth just prior to irrigation, where that is used; in the case of plaster, put in with the grain; in that of lime it should be put in just before a rain, or irrigation, and not at the same time with the grain or other seed. The amounts to be used of either of these substances will, of course, depend altogether upon the quantity of alkali in the soil and upon the amount of surface evaporation allowed in cultivation. It therefore varies and must be ascertained by experiment or analysis in each individual case. Their effect is to convert the corrosive or otherwise injurious salts into "neutral" ones, such as Glauber's salt or common salt, which are from ten to twenty times less injurious than, *e. g.*, the carbonate of soda. It follows that, when soils are very highly charged with the latter substance, even its conversion into neutral salts may not suffice to render the soil capable of profitable culture. To effect this it may be necessary to aid the antidote by leaching-out in bad cases. On the other hand, the antidote will, in any case adapted to its use, aid either of the other methods of obtaining relief. The farmer afflicted with alkali should, therefore, not feel discouraged or disposed to condemn as useless any one of the measures of relief here described simply because the result is not perfect. The three should be combined, whenever possible, to the extent justified by the pecuniary value of the land.

In districts afflicted with the carbonate of soda in the soil it has been found in numerous cases that the simple use of gypsum, conjointly with summer tillage, to keep the soil loose has sufficed to enable land that never before produced anything of value to bear abundant crops. But the failure to secure a similar result in the neighboring fields, at times, has caused unnecessary discussions as to the utility of gypsum. It should be remembered that where the amount of soluble salts present in the soil is very large gypsum may mitigate, but cannot altogether relieve, the trouble; its action must be supplemented by other means calculated to remove the soluble salts from the soil. In case carbonate of soda should not be present, gypsum will effect no improvement at all. To ascertain this is not at all difficult. The presence of carbonate of soda or potash is generally indicated when the water standing on the low alkali spots is of a dark-brownish tint, from the dissolution of the vegetable matter or humus of the soil; in other words, it is what is popularly known as "black alkali". Such alkali will, moreover, impart a brown tint to paper dyed yellow with turmeric, or it will turn the juice of red cabbage green, or the color of blue litmus paper red. Again, if water be shaken up with gypsum and allowed to settle, and some of the clear alkali water added, the gypsum water will be rendered turbid.

Analyses of "alkali".—The accompanying table shows in detail the composition of "alkali" salts occurring at different points in California.

Table showing in detail the composition of "alkali" salts occurring at different points in California.

Locality.	Soluble salts in 100 soil.	Potassium sulphate.	Potassium carbonate (saleratus).	Potassium chloride.	Sodium sulphate (Glauber's salt).	Sodium carbonate (sal-soda).	Sodium chloride (common salt).	Sodium borate (borax).	Sodium nitrate (saltpeter).	Sodium phosphate.	Calcium phosphate (bone earth).	Calcium sulphate (gypsum).	Magnesium sulphate (Epsom salt).	Magnesium chloride (bittern).	Organic salts of lime and magnesia.	Organic matter.	Silica.	Total.	Antidote.
Corvallis, Los Angeles county	1.68	8.74			51.19		22.37				0.51							82.81	Drainage.
Westminster, Los Angeles county	0.49	20.62	6.59			61.48	10.57											99.26	Gypsum.
Anaheim, Los Angeles county							(‡)		(*)			(‡)	(*)						Drainage.
Riverside, San Bernardine county				(*)	77.45	0.69	22.17											100.31	
Merced bottom, No. 18, Merced county.					(*)	(†)	(*)								(§)				Gypsum.
Merced bottom, No. 19, Merced county.	1.00				3.88	63.09	1.21		10.72	4.10						17.01		100.01	Do.
San José, Santa Clara county	14.70		2.92		75.98	14.59	6.79											100.28	Do.
Benton, Mono county					(‡)	(†)	(‡)												Do.
Sherman island, Sacramento county.				0.19			5.94						93.17					99.30	Lime.
Curtis' ranch, near Stockton	8.73				75.85	6.97	16.38			1.18								100.38	Gypsum.
Overhiser's alkali soil, Stockton	0.15				13.26	52.74	33.98			1.83								100.91	Do.
Overhiser's alkali soil, Stockton	1.02				22.92	64.01	13.06			(*)								100.00	Do.
Hueneme, Ventura county		5.64			42.50		22.10					2.49	25.61	0.75				99.09	Lime, drainage.
Goshen, Tulare county	1.40				44.24	32.98	16.74			1.97						1.57		97.50	Gypsum, drainage.
Mojave, Los Angeles county			0.58		35.38	12.03	31.48			0.92						18.88	0.73	100.00	Do.
Colton, San Bernardino county					26.73	53.08	12.28			0.60						7.10	0.21	100.00	Do.
People's Ditch, Tulare county					1.22	88.09	1.00									9.21	0.48	100.00	Gypsum.
Sumner, Kern county					19.20		37.14					0.96	18.31			20.87		96.48	Drainage, lime.
Dos Palmas, San Diego county					29.60		29.44					0.77	1.25	12.34		23.67	2.92	99.99	Lime, drainage.
Lemoore, Tulare county					(†)		(*)					(*)	(¶)						Drainage.
Emigrant Ditch, Fresno county						(†)	(*)												Gypsum.
Collinsville, Solano county					(‖)		(‖)						(†)						Lime.
Skagg's Springs, Sonoma county		0.12		0.97		78.54	2.95	12.90	trace	Li Co 3 0.03	Ca Co3 1.08		Mg Co3 0.54	Sr Bd } Co3 0.13			3.42	100.68	Gypsum.

* Little. † Chiefly. ‡ Much. § Large. ‖ Some. ¶ Moderate.

A point of great importance to the agriculture of these regions appears from even a cursory inspection of the table, viz, that in many cases phosphates, nitrates, and potash salts form a notable proportion of the "alkali". These are the substances of which the withdrawal by cropping causes sterility of the soil, and the purchase of which forms a standing item of outlay in the farmers' accounts wherever a regular system of husbandry is established. Ordinarily they are found only in traces in the water permeating even the richest soils, the amount present being so small, or in such a condition of insolubility, that they are retained in the soils; but here we find them to be present in such large proportions as to form a regular part of the circulating soil-water, the inference being that such soils, when freed from the injurious portions of the "alkali", would be extraordinarily productive, and would remain so permanently, without any additional supply of manure, if it could be assumed that soil-water of similar composition would continue to ascend from below. But even if this should not happen, the amounts shown to be actually present in a soluble condition are far from insignificant in themselves, apart from their pointing to some prolific source of the supply. Taking, for instance, the case of Overhiser's "alkali" soil in the above table, we find that the apparently insignificant percentage of soluble phosphates, when calculated to percentage of the total soil (0.0064 per cent. of phosphoric acid), amounts in absolute weight per acre of soil taken 12 inches deep and weighing about 3,750,000 pounds to no less than 240 pounds, a quantity which, being absolutely available to crops, would, *e. g.*, suffice for sixteen crops of wheat of 25 bushels to the acre; or, expressed differently, it is equivalent to a ton of best commercial superphosphate, for which $45 would have to be paid. At least an equal amount must, moreover, be estimated to be present in the soil in the ordinary condition—mechanically absorbed and insoluble in water, yet available to plants. Hence, the above estimate of wheat crops, for which the soil contains an immediately available supply, must be at least doubled; and after that is exhausted there would still probably remain a supply as great as is ordinarily present in soils.

It should be noted that, in the case of these phosphates, the addition of gypsum would permanently prevent their being washed out of the soil, even in case the leaching-out process were to be resorted to; yet their availability to vegetation would not thereby be impaired. It is highly probable that in many cases where phosphates have not been determined by the analysis their presence has simply been overlooked, and that their occurrence is much more general than is now proven. The amounts of potash found in some of the "alkali" salts are so great as to justify the conclusion that the supply of this ingredient in the corresponding soils is practically inexhaustible; for the fact that they circulate in the soil-water proves that the soil must in the first place have been fully saturated with them, apart from what is actually in solution, and that in all probability the supply comes from the permanent water-table. To this extent the cultivators of such soils would be permanently relieved from the necessity of replacement by manure.

As regards the nitrates, it is obvious that they are locally formed in considerable amounts in the arid regions of North America as well as in that of Bolivia. Minute quantities can be detected in almost all cases in which the carbonates of sodium or potassium form a large proportion of the soluble salts, but it is only under exceptional circumstances of location and rainfall that they can accumulate to a notable extent. Such is the case of the alkali tract in the bottom of the Merced river from which specimen No. 19 was taken. It lies in a local basin of impervious limestone, and forms a low ridge, which is only exceptionally overflowed by the river, and that after previous rains, so that even the salts that have bloomed out on the surface are not usually washed away.

It is quite probable that in the cultivation of regions possessing a climate suitable to the generation of niter deposits the artificial addition of the latter as a commercial manure will rarely be necessary. Since nitrates are not retained in a soil percolated by water, the use of drainage or leaching-out of the soluble salts will result in the removal of this important fertilizing ingredient from the soil. When known to be present, therefore, the process of washing out should not be carried further each season than is needful for the success of crops, and all the means mentioned for reducing the injurious effect of the corrosive salts on the crown-roots should be employed. It goes without saying that in each case crops adapted to the particular circumstances will, other things being equal, bring the best returns. Experience has already in many cases demonstrated the extraordinary productiveness of some "alkali" lands when reclaimed by the means described.

Effects of irrigation on alkali soils.—During the past two or three years complaints of the increase of alkali on irrigated lands in the upper part of the San Joaquin valley, especially in the counties of Kern, Tulare, and Fresno, south of King's river, have become more and more frequent. During a personal examination of that region in March, 1880, this important matter was brought prominently to my notice by many farmers. Much difference of opinion prevailed as to the causes of the evil, but there was no question as to the fact of the increased "rise of the alkali".

The latter phrase, commonly used in this connection, really contains the clew to the whole problem. It is emphatically true that the alkali salts rise from below, through the agency of the water evaporating upon the surface. Irrigation has not only increased the amount of water evaporating from the surface, but it has also caused a much greater depth of subsoil to be drawn upon for its alkali. That in many cases the strata lying at depths of from 4 to 6 feet from the surface are much more highly charged with soluble salts than the surface soil is painfully apparent from the aspect of the material thrown out in digging the irrigation ditches and now lining the banks of the latter. In some portions of the "island" embraced between the several outlets of Kern river south of Bakersfield these embankments appear as though covered with snow, and the alkali can be bodily picked up by the handful. It would seem as though the rains would have leached these earth-piles long ago, but the rains usually falling in that region are so light that the soluble salts are only washed into the soil to a few inches from the surface, and within a few days after evaporation has again brought them back in the shape of a white crust. In digging wells in the light sandy soils of the "plains", from King's river southward, it has often been found that no perceptible moisture existed, even at the depth of from 20 to 40 feet, until after the region had been irrigated here and there for several years. The amount of water needed is at first very large, but when the soil is once filled down to the drainage level one-half and even one-third of the water previously used will suffice to grow a grain crop.

The rainfall in this region is usually so small (from 4 to 8 inches) as to suffice only for moistening the soil to the depth of a few feet, and during the time required for the evaporation of this natural moisture the short-lived vegetation of the region rapidly passes through its development. That vegetation consists of a comparatively small number of species of bright spring flowers, which in their season cover the entire country with a dense and beautiful carpet, one and the same flower occupying the ground almost exclusively at times for many square miles by virtue of the law of the "survival of the fittest". Were there any crop of a habit similar to these flowers that could be profitably grown on these plains irrigation could obviously be dispensed with. The settlers of the region have tried what seems to be the next best thing, viz, to grow grain crops of a short period of growth, and therefore needing irrigation only during a small portion of the dry season. In so doing they have moistened the soil to a considerably greater depth than was reached by the rain-water before, and, as a consequence, the annual evaporation has greatly increased. The irrigation water, moreover, has brought with it from these depths all the supply of alkali salts that before had gradually been washed beyond the reach of the ordinary rainfall by an occasional wet season. Each succeeding irrigation, followed by evaporation, tends to accumulate the salts nearer the surface, so that finally the root-crowns of the grain crops are "burnt up" before even beginning to head. The evil will, of course, be greatly aggravated if the water used for irrigation originally contains any considerable amount of alkaline salts, which are superadded to those already in the soil strata. Some important practical bearings of this point will be discussed further on.

Remedies for the "rise of the alkali".—It is obvious that the "rise of the alkali", following upon irrigation, cannot be remedied by the use of the chemical antidotes alluded to above. While they do convert the most injurious salts, carbonate of soda and sulphate of magnesia, into much less active compounds, yet these will remain in the soil, and if in sufficient quantity will ultimately become noxious, especially to shallow-rooted vegetation. In some districts afflicted the natural alkali consists only of such "neutral" salts as common and Glauber's salt; as, for instance, in a part of the rich Mussel Slough country around Hanford, Tulare county, where at the time of my visit dead spots were appearing in the magnificent grain-fields when the grain was but a few inches high, the evil being worse wherever the crop was late and had not yet shaded the ground. Moreover, it was obvious and strikingly worse wherever the soil was sufficiently clayey to form a hard crust on the surface; a fact well known and recognized by farmers in the alkali regions, but often ascribed simply to the constriction of the stems by the contracting crust. The effect of the latter may, it is true, be noticed in adobe districts, where there is no alkali, and undoubtedly bears its share in doing damage; but the injury it creates is doubly great in alkaline soils.

In the early stages of the growth of cereals the pulverization of this crust may be accomplished by harrowing or rolling, with great benefit to the crop; but in the upper valley it can rarely be done after the last irrigation without considerable mechanical injury. That a soil having such a surface crust dries much more rapidly than the same soil when kept in good tilth is a fact too well known to require discussion. The dense crust absorbs water much more powerfully than does the loose soil beneath. The moisture is forcibly drawn from the latter into the surface crust, and there evaporates quickly under the influence of air and sunshine, hardening the crust more and more, and accumulating therein an increasing amount of alkali. To illustrate this, imagine a sponge, representing the loose soil, to be saturated with water, and a hard-burnt brick, representing the crust, to be laid upon it; the brick will take all the water from the sponge. Yet, if the brick be soaked in water and the sponge pressed on it, the sponge will not take up a particle of moisture. It is thus obvious that in alkaline soils the formation of a surface crust must of all things be avoided. In other words, as stated above, "deep and frequent tillage" is one of the foremost needs in such soils. And as this condition cannot be fulfilled in the case of broadcast crops, the conclusion is that broadcasting, and with it practically grain-growing, must ultimately be abandoned in the alkali regions and hoed crops substituted, which will admit of the ground being kept in perfect tilth throughout the season.

Crops for alkali soils.—The condition of preventing evaporation from the surface is also measurably fulfilled by such crops as "alfalfa", which not only thoroughly shades the ground, but in addition causes almost the entire evaporation water to pass up through its deep roots to the leaves, so as not to reach the surface at all. Such accumulation of alkali in and around the roots as can occur under such circumstances is too much diluted to hurt the plant. The fact that the alfalfa succeeds perfectly on ground too much charged with alkali to grow grain is notorious, only care must be taken to prevent injury to the root-crowns while the plants do not yet cover the surface by timely irrigation.

If circumstances permitted the profitable cultivation of alfalfa on so large a scale, the alkali districts would perhaps have little cause to seek further. The experience with alfalfa, however, clearly points the way for the selection of crops better suited to the circumstances than grain, whose shallow roots are much more liable to alkali corrosion than is the case with the tap-rooted or other deep-rooted plants. It is among these, then, that the alkali regions should seek for crops of which the product shall be sufficiently valuable to bear the expense of inland transportation, under which these districts are now suffering. Next to these, the search should be for such as will be successful in alkali lands, provided the soil be kept well tilled through the dry season, *i. e.*, "hoed" crops.

In the former category, one of those standing foremost in promise is probably *cotton*, the success of which in that region is already shown by experiments made, the profitable production being at present limited only by the demand for the staple on this coast, which may soon be increased by the establishment of cotton factories. Of other textile crops, hemp, jute, and ramie at once suggest themselves for trial.

Of oil crops, the castor bean is perhaps the most available and most certain of success, always excepting the despised "white mustard" or "wild turnip", whose rank growth as a weed shows what might be done with it if grown for the manufacture of rape-seed oil. Root crops, being too bulky for profitable shipment by rail, will not be available to any great extent at present unless as dairy feed, in conjunction with alfalfa, for conversion into butter and cheese; but beets, carrots, turnips, sweet potatoes, etc., all fulfill, to a greater or less extent, the conditions above formulated for successful culture in alkali soils. The culture of fruits, both large and small, that can be shipped in the dried condition, or in the shape of jellies, etc., is also an available industry, scarcely yet touched in the alkali regions. Raisins and prunes especially deserve attention as pretty certain of success.

Among hoed field crops available for that region sorghum and sugar-cane deserve attention. It is true that in general the presence of a large supply of soluble salts in the soil is deemed unfavorable to the profitable production of sugar, since it is apt to render the juice difficult to crystallize and to increase correspondingly the proportion of molasses produced. Actual trial, however, can alone determine the question here.

It would really seem as if, in the broadcast culture of cereals, the farmers in the alkali districts had made the worst possible selection for the permanent good of agriculture in their region. That a change of system in this respect is imperative can hardly be questioned by any candid observer of the facts. And it may well be questioned whether the necessity imposed by nature, of more varied and careful farming than has heretofore obtained, may not prove a blessing in disguise when rightly understood and acted upon. The planting system enriches a few individuals, almost always at the cost of the soil's permanent productiveness. It is small farms and intelligent culture that constitutes the prosperity of an agricultural community.

Sub-irrigation vs. Surface irrigation.—The injury arising in alkali lands from the formation of a consolidated surface or crust subsequent to irrigation by flooding suggests at once the application of the water in such a manner as to avoid this evil, viz, by sub-irrigation. To a certain extent the advantage so secured is well understood in the irrigation districts, the water being often applied only by the use of furrows or ditches, which divide the land into narrow bands, and from which the soil is moistened by "soaking sideways" from the ditches. The great multiplication of the latter, and their interference with the operations of culture on the large scale, have generally caused the use of this mode of irrigation to be restricted to small cultures. Even a cursory inspection of the state of things in the alkali regions shows that in the plots sub-irrigated by ditches the rise of the alkali has, as a rule, been very much less than in the case of adjoining ones irrigated by flooding; and, in the latter, the high spots that have not been covered with water frequently escape damage, while the low portions are scorched with the alkali. This, at least, is the result when the amount of alkali present is not very great. When the soil is very heavily charged, the high spots, being the first to dry, are also the first to be injured by the alkali drawn to the surface by evaporation, while in the low spots the grain may reach a greater development before being killed. Manifestly the object to be attained is to prevent the irrigation water from reaching and evaporating from the surface at all, if possible. To accomplish this fully it would be necessary to know how far upward water will rise when applied to the several soils. Some data concerning this point are given in books on agricultural science, but they are not of such a character as to permit the prediction of this measure with respect to any other given soil. We know in general that in coarse, sandy soils water rises rapidly, but only to a moderate height, stopping there; while in soils composed of fine materials, whether clay or fine silty matter, or both mixed, the rise is slow, continuing for months in some cases before reaching the highest point, which may, however, be twice or three times as much above the water surface as in the case of sandy soils. For instance, in coarse, sandy soils, like those of portions of the plains of Tulare or of parts of Stanislaus, the water may, in the course of three or four days, reach its highest point at 20 inches; while in adobe soils, or in the gray silt soils of Eel or Santa Clara rivers, it may take ten days to reach the same height, but will continue to rise slowly for several months before reaching the maximum height of about 50 inches.

The coarse sandy soil represents not only its kind, but also any well-tilled soil; while, on the other hand, the adobe soil illustrates the case of any compact soil, whether naturally so or rendered so by imperfect tillage or the prevalence of carbonate of soda. The extreme slowness of the ascent of the water toward the end of its possible rise shows why a poorly-tilled adobe soil will open into gaping cracks a short time after the cessation of rains; while a well-tilled soil, maintaining both a quicker supply from below and a slower rate of surface evaporation, may maintain moisture throughout the dry season. At the same time it informs us that sandy soils stand in especial need of a more dense subsoil, capable of drawing up moisture from greater depths than it is possible for a sandier mass to do, thus supplying moisture to the roots of plants, while allowing but little surface evaporation. As between the same soil in a state of tilth or such compactness as would result from packing by heavy rains, experiment has shown that the rate of ascent is in clay soils easily reduced to one-half or even less.

The many and somewhat complex bearings of this subject on the chief varieties of soils in the alkali region will form the subject of farther investigation, now in progress. One point, however, may even now be usefully discussed, viz, that while it is certain that water applied to a coarse sandy soil, at the depth of 24 inches, cannot reach the surface at all, and can, therefore, evaporate but very slowly, and not in such a manner as to accumulate alkali to an injurious extent near the surface, it does not, therefore, follow that in order to produce the same result in the adobe or silt soils the water has to be applied at the maximum depth of 50 inches; for in a field planted with any growing crop the leaves of the latter evaporate a very large amount of moisture, thus intercepting that which would otherwise rise to the surface and evaporate there. This is a matter of every-day experience. The inference is, that ditches or pipes designed for sub-irrigation would not in such soils require to be laid to any unreasonable depth in order to prevent the rise of alkali resulting from surface evaporation.

It is obvious that in this connection the subject of sub-irrigation by means of a system of pipes, of whatever material, acquires exceptional interest for the alkali districts, since its judicious use would not only obviate the rise of the alkali, but would also accomplish a great saving of irrigation water—the latter being a matter of especial importance where the water itself is somewhat tainted with alkaline salts. That this system is not likely to be used in connection with the growing of field crops on a large scale is true, since the expense of the pipes is too great for any land not yielding very high returns; but when the continued rise of the alkali renders lands, intrinsically fertile, incapable of further production under the system of surface irrigation, the owners will needs have to take their choice between its abandonment and the adoption of such systems and objects of culture as will yield them profitable returns under the circumstances. The culture of cereals must "go to the wall", and that of grapes, fruits, and such other crops as can be made to yield high returns under intense culture must take its place. It is not, perhaps, unreasonable to hope that the improperly so-called "asbestine" sub-irrigation pipe (consisting of hydraulic cement pipe, that can be cheaply and rapidly laid by a special appliance, at an expense not exceeding, it is said, $35 per acre) may become so generally available by the home manufacture of the material as to form a practical solution of this great problem.

It should not be forgotten that, with a slight change in the manner of laying and outletting, this sub-irrigation pipe may be made to serve also for underdrainage; so that land provided with it could be completely leached of its surface alkali by flooding during the season when water is abundant.

LAKE AND RIVER WATERS OF THE GREAT VALLEY, AND THEIR QUALITY FOR IRRIGATION PURPOSES.—In the foregoing discussion of the "alkali" question it has been tacitly assumed that the soluble salts already in the soil alone need to be considered, the water used in irrigation being regarded as pure water only. This, however, is far from being actually the case with any natural water, and in the alkali districts especially the irrigation water is almost always more or less impregnated with the very same salts whose presence in the soil is so objectionable. It is obvious that, when the amount of salts so added annually is at all considerable, it may ultimately so swell the quantity in the soil as to give rise to trouble. My attention was first directed to this subject by reports from the lands bordering upon Tulare lake to the effect that, although to all appearance of the best alluvial character, they would either not produce at all from the outset, or else would cease to produce after a few years when irrigated with the water of the lake. The beginning of the investigation of this subject was given in the report of the California College of Agriculture. A soil from the southeastern corner of the lake had been analyzed and found to contain in abundance all the elements of fertility; yet it would produce nothing, and that under circumstances which led me to believe that the trouble was caused by alkali (carbonate of soda) contained in the soil. Analyses seemed to confirm this supposition, but at the time the report went to press the water of Tulare lake itself had not been examined. Water samples were soon afterward received and analyzed, and the result showed it to contain so much alkali of the most corrosive character as to render it utterly unsuitable for irrigation. It then became apparent that one of the great bodies of water in the state that had been counted upon for irrigation purposes might have to be altogether rejected. The importance of the question led me to make the matter the subject of special inquiry during a visit to the upper valley, made under the auspices of the United States census, in March of the present year.

A personal examination of Kern lake, and of the region lying between it and Buena Vista lake, as well as of the Mussel Slough country, in Tulare county, satisfied me that in none of these rich agricultural sections could the slightest increase of alkali be safely risked; and analyses subsequently made of the waters of both Kern and Tulare lakes prove that a very few years' use of the water now filling either of these reservoirs would be promptly fatal to the productiveness of the lands irrigated. As regards Kern lake, this is obvious enough from a casual examination and tasting of the water. Having been shut off from the natural influx of Kern river for a number of years, it has been rapidly evaporating and receding from its former shores, so that at the time of my visit a difference in level of over four feet had been produced in fifteen months, leaving high and dry a boat wharf built at that time. About eighteen months before all the fish and turtles in the lake had suddenly died, creating a pestilential atmosphere by their decay, and even the mussels were mostly dead, a few maintaining a feeble existence. A strong alkaline taste and soapy feeling of the water fully justified their choice of evils. The tule marsh, laid dry by the recession of the lake, was thickly crusted with alkali, and the tules were dead, except where still moistened by the water of the lake, showing that the latter was not yet too strong for such hardy vegetable growth, albeit fatal to animal life.

Buena Vista lake was stated to be in a similar condition, but not yet quite so far advanced in evaporation, and still maintaining some animal life in its waters, having lost its connection with the river more recently. Tulare lake is well known to be full of fish, and as it annually receives the overflow of Kern and the regular inflow of King's river its evaporation and recession has been much slower; yet its water's edge is now distant several miles from the former shore-line, and as the water of the rivers is more and more absorbed by irrigation it will doubtless continue to recede until a point is reached at which the regular seepage from the irrigated lands will balance the evaporation. This epoch would seem, however, to be quite in the future as yet, for the rate of recession has, apparently, not sensibly changed in the last few years.

It is not likely in any case that the water of the lake will be more abundant or less impregnated with mineral matter than is now the case at the time when the state of equilibrium shall have been reached. In order to assure a fair determination of this important point water samples from the opposite ends, as well as from the middle of Tulare lake, have been analyzed, with the results given below. The sample of Kern lake water was taken by myself on the north shore of the lake, March 24, 1880. Tulare lake water No. 1 was taken about 300 yards off shore, near the southeast corner of the lake, inside of Root island, near land lately reclaimed by Mr. E. R. Thomason, of San Francisco. Samples Nos. 2, 3, and 4 were taken, according to my directions, near the middle of the lake, under orders of the King's River Canal and Irrigation Company, respectively at the surface, at 10 feet depth, and at 20 feet depth. Of these, only one (No. 3) was fully analyzed, the total of solid contents only being determined in the case of the others, whose composition could not, of course, differ in any material respect. No. 5 is water taken by Mr. E. Jacob, of Visalia, at a point off the mouth of Mussel slough, in the estuary of King's river, March 28, 1880. The sample was taken from the surface at a time when a strong northwest wind prevailed, which of course had a tendency to bring a larger admixture than usual of the fresh water of King's river.

Composition of the waters of Kern and Tulare lakes.

[Grains per gallon.]

	Total residue.	Carbonate of soda.	Common and Glauber's salts, etc.	Carbonates of lime and magnesia, and silica.	Vegetable matter.
Kern lake	211.50	64.37	115.41	9.29	22.43
1. Tulare lake, south end	81.49	27.92	37.85	13.44	2.28
2. Tulare lake, middle, surface	81.95	35.30	35.96	5.37	5.32
3. Tulare lake, middle, 10 feet below surface	81.83	30.46	39.49	7.47	4.41
4. Tulare lake, middle, 20 feet below surface	81.72				
5. Tulare lake, near mouth of King's river	38.55	13.46	15.01	5.11	4.97

To convey to those unaccustomed to the consideration of such matters an idea of the meaning of the above figures, it may be stated that the solid contents of river waters vary usually from 5 to 12 grains per gallon. The water of Tulare lake, where it is undiluted by the inflow of King's river, is therefore about ten times, and that of Kern lake about twenty-six times, stronger than an average river water. Even this, however, conveys but an inadequate idea of the relation sustained by these waters to organic life. The average sea-water (containing mainly common salt) is about ten times stronger than the water of Kern lake as regards its solid contents; yet in sea-water fresh-water fish live freely during part of the season, while in Kern lake the fish died at a time when, according to a minimum estimate, the water must have had about twice the strength of Tulare lake, or about one-thirteenth of the strength of sea-water. This shows strikingly the deadliness of the Kern lake alkali as compared with sea salt, or, in other words, of Kern lake water as compared with tide-water.

In comparing the quality of the alkali of Tulare lake with that of Kern lake we find that in the former the proportion of the carbonate of soda (being the chiefly injurious ingredient) is about 1 to 2.83 of the whole solid contents, while in the latter this ratio is 1 to 3.28.

A part of this difference is, however, due to the large amount of vegetable matter dissolved in the strong lye filling Kern lake; and, when allowance is made for this, the ratio becomes nearly the same in both waters.

As regards the relation between common and Glauber's salt on the one hand and carbonate of soda on the other in these several cases, it appears that in the evaporation process there is a gradual relative decrease of the carbonate of soda, for we have for this ratio:

Locality.	Carbonate of soda.	Common and Glauber's salt.
Tulare lake, near mouth of King's river	1	1.11
Tulare lake, middle	1	1.29
Tulare lake, south end	1	1.35
Kern lake	1	1.78

Whether this change in composition arises from a chemical change of the carbonate of soda or from an actual accession of the other salts is not easy to determine. The latter is the more probable explanation, inasmuch as actual veins and strata, several inches thick, of what from the description appears to be mainly Glauber's and common salt have been found in the region between Tulare and Kern lakes in digging ditches. But whatever may be the cause of this slight difference in the composition of the alkali in the different portions of Tulare lake, that difference is not sufficient to invalidate the broad conclusion that the water of that lake, as at present existing, is unfit for any of the ordinary processes of irrigation.

To prove this it is only necessary to consider what is the amount of the alkali that, under the usual practice, would accumulate near the surface. Ten inches of water is the usual estimate of what is needed in the course of the year to perfect a crop. Now, 1 gallon of water will cover about 1½ square feet 1 inch deep, or two-thirds of a gallon 1 square foot, or 6⅔ gallons per square foot is equal to 10 inches depth of water. Assuming the average solid contents of lake Tulare water at 80 grains per gallon, this quantity, upon evaporation, will leave near the surface, upon each square foot irrigated, 533 grains, or about 1⅓ ounces of alkali. This amount, pulverized and strewn over the surface, would cover the whole of it thickly with a white deposit—a phenomenon already but too familiar to the farmers of that region. That the operation could not with impunity be repeated many years on any soil, least of all on such as are already more or less charged with alkali, scarcely requires discussion.

To illustrate the latter point, a tule soil, taken by Mr. E. Jacob, of Visalia, from his land near the mouth of Mussel slough, was leached with water to ascertain the amount of alkali present. This was found to be 0.32, or about one-third of 1 per cent. Of this, supposing it to be of the same composition as that found in the water of the lake, about three-eighths, or, otherwise expressed, one-eighth of 1 per cent. of the whole soil is carbonate of soda, amounting to over 2 ounces in each cubic foot. This is within the limits of endurance of ordinary vegetation, at least in so fertile a soil; but double or triple it by evaporation, and that limit is passed.

To this conclusion, nevertheless, it is objected by some that the borders of Tulare lake are thickly edged with vegetation in many places, and that in some cases garden plots have been successfully irrigated with the lake water for several years. One such case is reported by Mr. Jacob, of Visalia, who took sample No. 5 of the table of analysis from the mouth of a small canal serving for the irrigation of a vegetable garden, which was doing well at the time. A few other similar cases have been mentioned to me. These, however, do not invalidate at all the conclusion that the lake water cannot serve for general irrigation as usually practiced. Even the strongest water in the lake, near its southern end, is not so strong as to injure the roots with which it comes in contact so long as it is not concentrated by evaporation. But in the low tule lands thus far tried this cannot occur to any great extent, on account of the constant presence of surplus water and the frequently repeated irrigation, by which the strength of the alkali in the soil is kept below the point of injury. It would be quite otherwise where the same water, used sparingly two or three times during the season, would evaporate so as to accumulate all its alkali near the surface; yet it is probable that if the soil so irrigated were to be leached by a very copious and continued flooding once a year, so as to carry the accumulated alkali into the underground drainage, the water might be used with impunity. This would be especially the case with land underdrained, and could be more readily accomplished the smaller the amount of water originally used. The minimum amount, undoubtedly, would be the outcome of pipe sub-irrigation, and would be applicable to the case of orchards, vineyards, etc. It might even be possible in some cases to make the same pipe system serve the purpose of irrigation at one time and that of underdrainage at another; but, in whatever way accomplished, a leaching-out of the alkali, accumulated from evaporation of such waters from time to time, would be a necessary condition of their continued use for irrigation purposes.

This principle applies, in fact, to many more cases than is ordinarily supposed. Irrigation, without proper provision for drainage, has in the past, in very many cases, been the cause of the abandonment of lands, once abundantly fruitful, which were supposed to be exhausted by culture, but in reality had simply become overcharged with injurious salts, or alkali, from the ever-repeated evaporation of enormous quantities of water, whose solid contents, though naturally very small, had nevertheless been too strongly concentrated in the soil. This naturally leads us to the consideration of the river waters of the San Joaquin valley and their relation to the origin of the alkaline character of the waters and soils of the upper valley.

Geological history of the valley of California.—That the great valley of California was in remote (Quaternary) times a great inland lake, which disappeared in consequence of the breaking through, first, of Carquines straits, and afterward of the passage of the Golden Gate, is a matter scarcely doubted even by the casual observer. A glance at the map also shows that, from some cause not yet fully understood, there exists in the southern part of Fresno county a ridge across the valley by which the waters of King's river are thrown southward into Tulare lake. At present this ridge is intersected at its western end by Fresno and other sloughs, through which the surplus waters of Tulare lake or of King's river can find their way into the San Joaquin. But previous to the formation of this outlet the entire upper valley evidently was a shallow lake, of which Kern, Buena Vista, and Tulare lakes are the remnants. From the data given below, it appears certain that the entire lake of the great valley had a somewhat alkaline water; and they also show that probably the residuary lake of the upper valley was more strongly so at first, and rendered more so in the course of long periods of evaporation, during which "sheets of alkali" (to use the language of the workmen who dug the Kern canal) were formed among the alluvial deposits of the western margin of the valley.

It is only thus the fact already alluded to, viz, that the deeper portions of the Kern valley alluvium are most strongly impregnated, can find its explanation. Whence did all the alkali come? A partial answer to this question is readily found in the frequent "blooming out" of soluble salts on the face of hillside cuts. Evidently a good deal of such salty matter pre-exists in the geological strata of the valley, and must be continually washed out by percolating water, which carries it into the lower portions of the country, and finally into the lakes themselves. But it would be difficult to account for the large accumulations of these salts in the Kern valley if there were not some more copious and lasting source. For this we would naturally look to Kern and King's rivers themselves, and analyses of the waters of these rivers were accordingly made, with the results given below.

Analyses of waters of the great valley.—At my suggestion, an investigation of the waters of the chief rivers entering the valley between King's river and the Sacramento was undertaken by Mr. Horace G. Kelsey, of Merced Falls, as a graduating thesis at the University of California. This includes the results given below under Nos. 12 to 15, both inclusive. The analyses of the water of the Sacramento and Los Angeles rivers were made for the state board of health by Mr. Walter Jones (of the class of 1878, University of California) and published in the report of that body for the year 1878. To facilitate comparison, the table includes again the analyses of the lake waters already given above, and also an analysis of the water found a few feet beneath the surface at Point of Timber, Contra Costa county, near the junction of the San Joaquin and Sacramento, in such abundance as to suggest its use for irrigation.

No. 1. Water from Los Angeles river, taken from a hydrant in the city of Los Angeles, September, 1878.

No. 2. Water taken from the grand cañon of Kern river in April, 1880.

No. 3. Water from irrigation ditch of the Kern Valley Irrigation Company, taken at a point 2 miles below Bakersfield. Both the above samples were furnished by the superintendent of that company. The water at that time was just beginning to receive the melting snows, and was slightly turbid, and of course somewhat diluted, as compared to its condition in winter.

Nos. 4 to 10 have been described as above.

No. 11. Water taken from King's river at Kingsburg, June 19, 1880, by Mr. J. D. Schuyler, of the state engineer corps.

No. 12. Water taken from King's river at Kingsburg, in November, 1880, before any rains had fallen.

No. 13. Water taken from the San Joaquin river at the crossing of the Southern Pacific railroad, in November, 1880, after the first rains; perfectly clear.

No. 14. Water taken from the Merced river at Snelling, Merced county, in December, 1880, after the first rains had raised the river slightly above the lowest water-mark. It was slightly turbid with clay, which filtration could not remove, but was eliminated after evaporation.

No. 15. Water taken from the Mokelumne river at Woodbridge, San Joaquin county, in November, 1880, after the first rain, which had slightly raised the river. Water slightly opalescent from suspended clay, and residue corrected for same, as in No. 14.

No. 16. Water of the Sacramento river, taken from a hydrant in the city of Sacramento, September 19, 1878. The data have been recalculated from the published results, so as to conform to the mode of presentation here adopted, which explains the apparent discrepancy of the tables as here given.

No. 17. Water from a well at Point of Timber, Contra Costa county, furnished by Mr. T. W. A. Carter, of that place. This water is found abundantly about 8 feet below the surface in that region, and, if available for irrigation, could be obtained in unlimited quantities by pumping, but the inhabitants stated that it "would kill the soil".

Analyses of waters from the San Joaquin valley.

[Grains per gallon.]

	Total residue.	Carbonate of soda.	Common and Glauber's salts, etc.	Carbonates of lime and magnesia and silica.	Vegetable matter.
1. Los Angeles river	14.30	....	8.46	5.84	....
2. Kern river (cañon)	9.49	1.22	1.77	5.55	0.95
3. Kern river (ditch)	9.62	1.23	2.21	5.33	0.85
4. Kern lake	211.50	64.37	115.41	9.29	22.43
5. Tulare lake (south end)	84.44	27.92	37.85	13.44	2.28
6. Tulare lake (middle surface)	81.95	35.30	35.06	5.37	5.32
7. Tulare lake (middle, 10 feet below surface)	70.36	30.46	28.10	7.39	4.41
8. Tulare lake (middle, 20 feet below surface)	81.72	....	....	....	....
9. Tulare lake (near mouth of King's river)	38.55	13.46	15.01	5.11	4.97
10. Tulare lake (near outlet of west side canal, 10 feet below surface)	76.00	30.95	33.95	6.60	4.50
11. King's river (June)	4.13	....	0.86	3.27	....
12. King's river (November)	5.03	....	....	....	0.19
13. San Joaquin river	4.54	0.45	0.15	2.15	0.80
14. Merced river	5.64	0.19	0.09	4.18	....
15. Mokelumne river	6.97	....	0.42	4.42	3.70
16. Sacramento river	6.60	0.27	4.02	2.41	....
17. Point of Timber (San Joaquin delta), well water	67.75	10.83	48.41	7.41	1.10

The following table shows more in detail the composition of three of the waters given on page 71 in a general manner:

Ingredients.	Los Angeles, city hydrant, river water.	Tulare lake, middle, ten feet below surface.	Sacramento river, city hydrant.
	Grains per gal.	*Grains per gal.*	*Grains per gal.*
Carbonate of soda	....	30.46	0.27
Chloride of sodium (common salt)	1.00	20.27	} 1.42
Sulphate of sodium (Glauber's salts)	4.14	7.54	
Carbonate of lime	0.38	2.49	0.31
Carbonate of magnesia	4.20	4.21	0.25
Silica	1.17	0.69	1.85
Sulphate of lime	0.78	....	0.42
Phosphate of lime	2.18	....	1.48
Iron and manganese carbonates	0.26	....	0.63
Alumina	0.10	0.29	0.07
Vegetable matter	....	4.41	....
Total residue	14.30	70.36	6.70

In discussing the quality of these waters in reference to irrigation it must be understood that the group of ingredients mentioned in the fourth column of the first of the above tables, viz, carbonates of lime and magnesia and silica, are not only useful to vegetation, or unobjectionable, but are also very soon deposited and retained in the soil. We therefore leave them out of consideration so far as the alkali question is concerned. For this the carbonate of soda and the salts mentioned in the third column are of chief importance, and among these the corrosive carbonate of soda is the most noxious by far. The prominent facts shown in the above table may be thus stated: The water of the Los Angeles river, though containing a large aggregate amount of solid ingredients, has none of the carbonate of soda, but only neutral and earthy salts, of which a very large amount only is injurious. This fact, together with the perviousness and free drainage of the lands irrigated, explains why it is that even those which have been longest under cultivation and irrigation in that region do not show any serious increase of alkali, and may never do so if abundance of water is used, at least from time to time. But as irrigation water becomes more closely utilized and relatively more scarce the leaching process will occur less frequently, and the accumulation of alkali salts near the surface will become more and more apparent.

In the water of Kern river the proportion between the carbonate of soda and the other salts is almost the same as in the water of Tulare lake, in the proportion of about 1 to 22. In other words, if 22 gallons of Kern river water were boiled down to 1 gallon, the alkali in this water would, in quantity and quality, be the same as in the water of Tulare lake; and if this gallon was still further reduced to about three pints and a half, the remaining water would have about the composition of the water of Kern lake, as it was in March, 1880. Comparing the water of King's river with that of Kern river, we find that in the latter the aggregate amount of solid residue in the water is less than half that found in Kern river. This, however, is to some extent due to the season at which the water was taken, it being then diluted with snow water. For purposes of comparison we should take the figure obtained for the residue in November, when the solid contents were at their highest amount. But even on this basis we find that the amount of carbonate of soda in the King's river water is utterly insignificant, being not yet one-hundredth of a grain per gallon, against about one and a quarter grains per gallon of Kern river water, while on the same assumption the percentage of other soluble salts is about twice as great in the latter.

Of the other rivers of the valley the San Joaquin shows the highest amount of carbonate of soda, but yet only about one-third as much as Kern river. The Merced has less than one-sixth as much of the same, the Sacramento less than one-fourth. Between the latter two we find the Mokelumne with none at all, there being some chlorides of magnesium or calcium in solution to the extent of about one-tenth of a grain per gallon—an insignificant amount. The water of the Los Angeles river likewise is free from carbonate of soda; but its aggregate of soluble salts is somewhat high, exceeding in this respect even Kern river by 1¼ grains. It is credited with a very large proportion of phosphates, as is also the Sacramento river. In the other analyses made these were not determined for want of material.

It appears from these comparisons that of the streams examined the Mokelumne has naturally the best water from the irrigator's point of view. King's river comes next, with a water whose purity is the more remarkable, as its sources lie so near those of the Kern. The Merced comes next, having somewhat less of the objectionable carbonate of soda than the Sacramento; but if corrected with gypsum its waters would be placed at head of the list as the purest of all. The San Joaquin river has the smallest total of solid content of all the waters taken at the same season, but contains over twice as much carbonate of soda as the Merced; if corrected with gypsum, its water would contain less than half as much of soluble salts as that of the Sacramento, one-half less than King's river, and only one-fifth as much as that of Kern river.

It will thus be seen that the correction of the irrigation waters of the valley by means of gypsum would in all cases but that of the Mokelumne effect a very important improvement as regards the safety of their continued use on soils of which but too many have already the full dose of alkali compatible with profitable cultivation. The change could doubtless be easily accomplished by interposing, at suitable points in the ditches, sluice-boxes filled with coarse fragments of gypsum, renewed from time to time as the action of the water converts the gypsum into carbonate, or common limestone; or the gypsum may be applied to the soil itself, and thus be made to neutralize not only the soda of the irrigation waters, but also that in the soil itself, at the same time introducing a useful fertilizer. The amounts to be thus used may effectively vary, according to circumstances, from 200 to as much as 1,000 pounds for the first application, smaller doses to be used thereafter at such intervals as experience may dictate. Precautionary measures of this character should be employed as soon as possible by the inhabitants of the fertile valley of Kern river. Those using its waters should keep in mind that their evaporation adds annually to the alkali already in the soil a small but not inappreciable amount, which in some cases may, after a few years, prove "the straw that breaks the camel's back"; and that therefore some of the means mentioned as remedies against this kind of alkali especially should be currently employed to keep it in abeyance. Tillage after irrigation, the planting of deep-rooted crops instead of grain, and the use of gypsum as a neutralizer of the worst ingredient, the carbonate of soda, are the measures that suggest themselves as the most feasible; while sub-irrigation, and especially the leaching out of the alkali from time to time by long-continued flooding and underdrainage, are more radical remedies for future use.

The water from Point of Timber offers some interesting points, suggestive of a state of things that may have to be taken into consideration in all plans for the irrigation of the west side of the San Joaquin valley. From its location, this water might have been conjectured to derive its ingredients from tide-water percolating into the loose strata. So far from this, its composition is closely analogous to that of the water of Tulare lake, except that the proportion of carbonate of soda is considerably less, and therefore it is not likely to be as injurious in its effects on vegetation. Yet the inhabitants report here also that to irrigate with it "kills the soil", *i. e.*, renders it unproductive. It will doubtless do so when applied in small quantities only, and repeatedly; but it is likely that if used as suggested in the case of the Tulare water (that is, so as to leach the alkali out of the soil once in a season into the underlying water-table) it might be successfully employed for irrigation, especially if, at the same time, the carbonate of soda were neutralized by the use of gypsum. If it be thought too fanciful to suppose, as has been done, that the alkali-water stratum at Point of Timber represents the seaward seepage of Tulare lake itself, it is nevertheless quite probable that it does represent the quality of the underground drainage of the west side of the San Joaquin valley, and is connected with the persistent appearance of "alkali spots" at every low place in the valley, from Antioch up to Kern lake.

With the lights now before us, it can hardly be regretted that the old Westside ditch, which was to irrigate the lower country with the corrosive waters of Tulare lake, was not successful. The lake level is now several feet below the bottom of that outlet, and the lake keeps receding annually, and its alkali becomes stronger as the mass of the water decreases. It is difficult to say where it will stop; but if, as is probable, a state of equilibrium is reached whenever the waters of Kern and King's rivers shall have fully filled the parched depths of the plains by a more general system of irrigation, it is not at all probable that the lake water will thereby become fresher; on the contrary, such seepage water will be likely to bring into it the alkali now dried up in the lower strata, and the annual evaporation will concentrate the solution more and more. It would certainly be most desirable to utilize the lake as a great reservoir for irrigation supply; but to render this practicable it would be necessary first to empty out or displace the mass of alkaline water at present occupying the basin. The discussion of the feasibility of such an undertaking, however, belongs to the province of the engineer corps.

From the facts above given regarding the alkali soils and irrigation waters of California the importance of investigating thoroughly not only the quantity but also the quality of the waters available for irrigation in the arid regions is sufficiently obvious. The facts as nature has made them should be elicited and plainly set before the people, so that money may not be invested in useless undertakings, or damage done which it may be difficult to undo thereafter. There are, probably, but few river waters in the world of such composition or natural purity that continued irrigation without correlative underdrainage can be practiced without in the end causing an injurious accumulation of soluble salts in the soil. In India, according to the testimony of Professor George Davidson, the evil effects of such practice have become painfully apparent, and to such an extent that after the expenditure of enormous sums for bringing the water upon the fields the government now finds itself face to face with the costly problem of its economical removal, by drainage, so as to relieve the soil of the accumulated "alkali", which has rendered it unfit for cultivation. An early attention to this matter, with such foresight as will prevent the occurrence of similar difficulties, cannot be too earnestly recommended to all interested in lands needing irrigation from the Pacific coast to Colorado and Kansas.

COTTON CULTURE IN CALIFORNIA.

HISTORY.—It is stated, and is in itself extremely probable, that the missionary padres introduced the cotton-plant from Mexico along with other culture plants; but no definite data on the subject are extant. As a textile fiber for home use the wool of sheep was mainly resorted to, the methods of production being better adapted to the indolent habits of the domesticated Indians, as well as to those of their Mexican successors.

Cotton culture began to attract considerable attention in California in 1856, at which time a premium of $75 was offered by the State Agricultural Society for the best acre of cotton. How long previous to that time its culture was engaged in to any extent is not known, but it was doubtless made the subject of experiment in very small tracts for a year or two. At the annual meeting of the society in that year no award seems to have been made, and the visiting committee reported that in their visits to different parts of the state they had seen a patch of cotton of extra quality at Monte, Los Angeles county, containing less than an acre; they thus leave the inference that no other growing cotton was seen by them. The president of the society, in his address at the same meeting, casually spoke of cotton culture as a successful experiment.

In the next year, 1857, the following report was made to the society by its committee of awards on sugar-cane, tobacco, and cotton:

> The committee also examined the several specimens of cotton, and, as with the cane, we have to report the successful growth of this great staple. We also examined in contrast Georgia upland cotton, and the growth in this state from seed taken from the same parcel, and the improvement in fineness of fiber of the native growth over the imported or Georgia grown was manifest and striking; and in this we have the concurrence of experienced spinners from the east. But the staple of the native is not quite so long, though fully as strong as the Georgia cotton. This we attribute altogether to the lack of moisture in the earth where it grew.
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> * * * * * * *
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> Several other samples examined rate as fair upland. The one from Slocum's Bridge has the advantage of staple and texture over any of the others. The samples grown in Los Angeles county are equal, if not superior, to the best Mississippi or Louisiana cotton, and of course superior to all others, and one grade below sea-island cotton. This sample is not of the sea-island seed, but of the gray Petit Gulf kind, proving conclusively the perfect adaptation of our climate and soil to the production of the very finest staple.

This last sample was grown on a loose soil, and was probably some of that seen growing the year previous by the committee. Samples of cotton grown in Shasta county this year were on exhibition also in San Francisco.

In the following years, although premiums were offered by the society, no awards seem to have been made, and only slight mention is made of cotton until 1862 (except in Kern and Sacramento counties in 1859), when the legislature, under the initiative of Mr. Robert Strong, of Merced, offered the following premiums: For the first 100 bales of cotton of 300 pounds each, $3,000; for the same quantity produced in the first, second, and third succeeding years, $2,000, $1,000, and $500, respectively. Other premiums were offered for cotton cloth.

At the next meeting of the legislature a supplemental act provided that one-half or one-quarter of these premiums should be paid to any person producing one-half or one-quarter of any of the quantities named in the original act. No awards seem to have been made, or even applied for, until 1865, when Mr. Mathew Keller, of Los Angeles, planted and raised 108 acres of cotton and received on the 22d of December the state premium of $3,000. In the same year there were a number of other cotton farms in the southern part of the state, one of 130 acres on Kern lake, in Kern county. The acreage for this and Los Angeles county was estimated at 450 acres, the average yield being one-third of a bale per acre. In Fresno county a farm of 100 acres was reported on Upper King's river, in Merced county, at Snelling; another of 100 acres on Upper King's river, in Fresno county.

In 1866 the report of the agricultural society reviews the subject of cotton culture as follows:

The history of the cultivation of cotton has also been an anomalous one in this state. Experiments on a small scale had been made for a number of years in different sections with gratifying success. Encouraged in part by these results, and in part by the very liberal bounty offered by the state for the first production in large quantities, several parties in the southern counties planted quite extensively in 1864. They all labored under adverse circumstances. Their seed was in great proportion of those varieties not adapted to our climate, being of the large, late varieties and of a poor quality, rendering replanting to a great extent necessary. As the parties referred to were competitors for the state bounty on a hundred acres, they strained every nerve, but more to secure the number of acres specified to be planted than to insure a proper cultivation of the crop after it was planted. But, notwithstanding all these unfavorable circumstances, they all produced a more or less creditable crop, those portions of their fields which were planted with the Tennessee upland and Petit Gulf seed making excellent crops both in respect to quantity and quality. One of the parties alluded to, in a letter to the secretary of this board, says: "The sum of our experience may be considered to be: First. That the Petit Gulf and the Tennessee may be considered the safest and most profitable, and should be planted as early as frost will allow. Second. That the low bottom and tule lands of the state are well adapted to the raising of cotton. Third. That from the hardy nature of the plants but little skill is required in irrigation, and that much less water is required than would be necessary in the successful cultivation of corn. Fourth. That the seasons in California are especially favorable to the production and the harvesting of cotton."

In this year cotton was raised at Folsom, Sacramento county. In 1867-'68 one-half acre was planted in Lake county, which yielded 50 pounds of lint, while in southern counties there were a number of cotton farms. In 1871 Colonel J. M. Strong, who had been experimenting on cotton culture since 1864, planted 100 acres of cotton on the Merced river lands. The seed was carefully selected, and, though planted on the 20th of June and cultivated only once, the yield was about 750 pounds of lint per acre. Previous crops on a smaller area and with indifferent seed had given him with one cultivation a yield of 500 pounds of lint per acre.

In this year cotton was produced also on the red-clay lands near Sacramento, on Butte slough, in Sutter county, and on the tule marshes at Knight's landing, Yolo county. At the latter place the sea-island variety was planted; it grew to a height of 5½ feet, but did not mature. On Cache creek bottom, in the same county, cotton grew 4 feet high, some of the stalks having each 200 bolls.

An experiment was also made at Colonia, in Santa Barbara county, but the cotton was planted on June 5, and did not mature well.

In 1872 the largest acreage of cotton was in Merced county, nearly 700 acres being planted in the vicinities of Snelling, Hopeton, and Mariposa creek, and two farms of more than 200 acres each were reported; 140 acres were planted near Bakersfield, Kern county, and smaller tracts in other southern counties. Cotton-gins were erected in Merced and Kern counties.

In 1873 the cotton acreage in Merced county alone was estimated to be from 1,500 to 2,000 acres. On the 11th of May of this year the first export of cotton was made from California, the Buckley Brothers, of Merced county, shipping 22,886 pounds by the ship Ontario to Liverpool. Among this was a small lot of Nankin cotton, which received high commendation at Manchester. The seed of this, however, has since been lost. The culture of cotton has been steadily continued on the Merced bottom farms ever since, with an acreage ranging from 350 to 500 acres.

The largest experiment in cotton planting reported from the Sacramento valley between 1872 and 1881 was that of Mr. J. L. Jackson on bottom land of the Sacramento river, in 1876. He planted 180 acres, and obtained a stand on 160 acres. Cultivation was somewhat neglected, and the cotton was not all picked, most of it only once. The product was 30,000 pounds of lint, or about 188 pounds per acre. The staple, of which samples were seen by me, was excellent. A number of smaller plantings were made in the same region about this time, but the want of a home market discouraged a continuation of the culture.

The personal observations made on the occasion of my visit to the Merced cotton farms in 1879 are given below in connection with the cultural details. The total acreage at that time was 375.

The following year (1880) a field of about 60 acres was planted at Belleview ranch of Haggin & Carr, in Kern county. This experiment was of especial importance, because covering a tract of land which, under continued surface irrigation, had become so strongly impregnated with alkali that it failed to grow wheat any more, and also because of a careful record kept of the cost and returns, which is given on page 76, from an article in the *Pacific Rural Press.* The financial exhibit there given is not very flattering, as might be expected the first year of trial; but it is a great deal better than could have been obtained on the same field with wheat. In any case, the outcome has been sufficiently satisfactory to induce the planting of a considerably greater breadth.

In the Mussel Slough region of Tulare county also some excellent samples of cotton were grown in 1881, and as the "alkali question" becomes more pressing and interferes with the success of wheat culture it is likely that cotton will become a favorite crop.

Experiments made with sea-island and upland cotton on 500 acres near Williams, Colusa county, and near Gridley, Butte county, seem to prove that cotton will yield good results in the Sacramento valley without either irrigation or the frequent rains considered so necessary to the welfare of the cotton-plant in the southwestern states. The sea-island variety, however, on both fields was a complete failure.

METHOD OF CULTURE.—The following method, given by Mr. J. W. A. Wright (*a*), speaking of the cotton culture in the San Joaquin valley, is usually practiced by those most prominently engaged in cotton culture:

To prepare the land some begin plowing in December and others not until February. As a general rule, the earlier the better. Some plow only 4 inches, while others plow as deep as from 10 to 12 inches. Planting is not done in ridges, as in the southern states, but (because of the drier climate of California) in furrows run about 4 feet apart. The time of planting varies from the last of March to the 10th of May, though successful crops have been raised when planted as late as the middle of June. "It has been found best to soak the seed in a pool of cold water, at least from twelve o'clock noon until early the next morning, and then to mix with ashes; this kills the eggs of the insects which often destroy the crop." The seed comes up in from five to fifteen days, according to the time of planting and to the depth to which covered. It should be covered about 2 inches. The plants, when up, are thinned out with a hoe, leaving one or two at distances of from 18 to 24 inches apart. The after-cultivation is less than that given in the southern states, especially on the uplands, where weeds are not very troublesome. Some planters plow three times and hoe once, others on bottom lands plow twice and hoe twice, at intervals of from twenty-five to forty days, beginning two weeks after the plant is up. By some the southern method is practiced of running the plow at the first plowing near the roots of the plant and throwing the soil from the plant, and at the second plowing throwing it back. The blooms begin to open toward the end of June, and the bolls begin to open in September. The plant attains a height of from 3 to 7 feet, with an average of 4 feet, and from 300 to 400 good bolls have been counted to the plant, averaging usually 100. Three pickings are sometimes given to the crop, the first in the last of September, the second in October, and the last toward the close of November. Some planters continue the picking into January or February.

In regard to irrigation, speaking of the San Joaquin valley, Mr. Wright says:

> The facts deduced from the experiments on cotton do not make it safe to establish definite rules for the time, amount, and frequency of irrigation. These matters are to be regulated by the moisture of the ground and the character of the seasons. As regards the method, some conduct the water in furrows, made with a 10-inch turning plow, within a few inches of the rows of plants; others flood the land after the cotton is up. Water has covered the plants twenty-four hours without apparent injury. When the crop has been flooded, it is indispensable to plow the land as soon as it is dry enough to bear a plow and team, say within a week after irrigation. The usual interval between irrigation is from thirty to forty days; the number of times usually three, beginning in May and ending in August. The natural moisture of the ground then begins rising toward the surface on our plains, and irrigation after that date is not essential. The most important point to guard against in irrigating cotton is not to allow the growth to be checked by want of moisture after the young bolls or squares begin forming and then renew the growth of the plant by irrigation. So surely as this is done, the squares already formed will drop off and the yield be diminished to that extent.

On a visit to the cotton farms of the Merced valley the following details were ascertained: The cotton acreage was (1879) 225 acres on the Strong farm and 150 acres on the farm of W. A. Grade, near Hopeton. On the former place the aspect of the plant was very uneven, those portions of the field having a shallow soil, underlaid by gravel, being hurt by drought, and it being almost too late for irrigation. On Grade's land the stand was more regular, the soil being more uniformly deep, the height of the plant being from 3 to 4 feet and fairly bolled, yielding that season 1,000 pounds of seed-cotton per acre; in good seasons easily averaging 1,200 pounds, making 300 pounds of lint, formerly 500 pounds.

The planting is done in March or the first week of April, there being little danger from late frosts here. Cultivation is level, the rows about 4 feet apart, and the plants from 18 to 24 inches in the row. The land is kept very clean, and is plowed or cultivated as often as may be rendered necessary by the season. One irrigation is given in June, just before the time the blooms begin to open; then no more, as it does not seem to be required, and trouble from weeds is avoided. The plants, originally from Mississippi (Petit Gulf) seed, have a curious habit of forming long branches from the base of the stalk, thus spreading more than is usually seen in the cotton states. Along these branches the bolls are strung thickly, sometimes apparently of the same age for 18 inches or 2 feet, and, especially in the low and somewhat over-irrigated grounds, are inclined to be slow in opening. Near the river such long, heavily bolled branches are having a new growth and are blooming abundantly, while not a boll seems as yet (October 14) inclined to open. On the higher ground the plants have mostly ceased blooming and the bolls are opening well, though somewhat slowly. This sluggishness in opening seems to occur to a greater or less degree all over the San Joaquin valley. Light frosts accelerate it materially. There is not usually any killing frost here; hence picking can be done very clean.

Picking is chiefly done by Chinese, who in that year were paid 90 cents per 100 pounds of seed-cotton. The best hands pick 180 pounds a day, the majority between 75 and 90 pounds. They carry a large sack slung over their shoulders, thus lugging along from plant to plant from 50 to 75 pounds at times; they use no baskets. It is very slow and awkward work compared to that done by the southern negroes.

a Lecture delivered at the University of California October 15, 1875.

Cottonseed has thus far been used for feed only, being sold to sheep-raisers at $4 per ton. The decrease in the average product of the land shows the loss from this mode of disposing of the seed, and it is strongly advised that it be regularly returned to the soil. A "Magnolia" 40-saw gin was being used in ginning. The staple is fine, long, and strong, as is shown by the measurements given in the preliminary part of this report, volume I.

Besides the large-scale experiments in the southern region above recorded, small patches of cotton have been grown there by small farmers and by the Mexican population for many years for home use. Since in that climate not uncommonly several years elapse without a "killing" frost, the plant is perennial, and bears several crops, the staple, however, becoming apparently shorter and more harsh as the plant becomes older. A sample of fiber from a three-year-old plant at San Diego is reported upon in the record of measurements made by Professor Ordway. It may be questioned whether in some cases the plantations might not be profitably continued through the second year at least, even with a somewhat inferior fiber, of which, however, on account of the long season, the yield would be very high. Further experiments on this subject are needed.

Cost of production.—The following estimate was made by Colonel J. M. Strong, of Merced county (who had been a planter for several years), on the basis of 200 acres in 1872:

Twelve hands, $25 per month	$3,600 00
Feed of team	500 00
Feed of hands	1,500 00
Extra gathering	500 00
Ginning and baling	500 00
Blacksmithing	100 00
Total expenses for 200 acres	6,700 00
Total expenses for 1 acre	33 50

The yield was 150 bales, making the average cost $44 66 per bale, or about 9 cents per pound of lint. This, with an average of from $6 to $8 per acre for planting and cultivation (against $33 50 above), would make the total cost of production about 4½ or 5 cents per pound of lint when the yield is 500 pounds of lint per acre.

The following estimate is that of Mr. J. B. Haggin as the result of the cultivation of 59.12 acres of cotton in Kern county in 1880:

Plowing	$104 50
Irrigating	120 50
Hoeing	295 50
Picking	578 00
Ginning and baling	99 61
Rope and twine	32 78
Burlap	23 05
Seed	33 48
Total	1,287 42

In addition to the above the following expenses are considered:

Hauling to depot	12 37
Railroad freight	108 14
Storage	10 70
Commissions	24 88
Total cost	1,443 51
Sales at from 12 to 14 cents per pound	1,990 05
Balance above cost	546 54
Cost per pound to make and bale at ranch	0 08
Cost per acre to make and bale	21 77
Cost per pound to make, bale, and deliver in San Francisco	0 09
Net profit per acre	9 24

The yield and quality of cotton was good. A sample was sent to New Orleans, and valued there at 12½ cents. This was the first year of cultivation, and many difficulties were encountered: first, the seed was old; second, there was a difficulty in having the cotton picked—white men will not pick, and not many Chinamen were found that could; third, the use of the gin for the first time.

Conclusions.—From the record above given it appears that cotton has been successfully grown at many points, practically covering the whole of the great valley, a part of the foot-hill lands of Shasta and a part of Napa county, and to the southward all the agricultural portion of the southern region. By inference drawn from similarity of climate and products, without direct test, we may include within the possibly cotton-growing portions of the state the valleys of Napa and Sonoma, the agricultural portion of Lake county, the foot-hill region of Tehama, and the entire "lower foot-hills" of the Sierra. On the other hand, all the Bay region, as well as the seaward valleys of the entire Coast range, are excluded from the cotton-growing area by reason of the cool summers, trade-winds, and fogs to which they are subject.

In addition, it may be broadly stated that in the Sacramento valley cotton may on deep soils be grown without irrigation, while in the San Joaquin valley it, like all other crops, must be irrigated to insure profitable returns. The best experience seems, moreover, to indicate that, as in the case of the vine, the minimum irrigation that will enable the plant to develop is that which on the whole gives the best results, inasmuch as late irrigation especially tends to retard the opening of the bolls and in the low portions of the fields to start new growth, leaving the older bolls stationary.

The sea-island variety is a failure thus far wherever tried. That cotton culture has not assumed larger proportions in California as yet is adequately explained by the fact that the home market is, in the absence of cotton factories, extremely limited, and the long distance from the world's markets renders competition with the Atlantic cotton states on the one hand and with India on the other a doubtful matter, which could be turned in favor of California only by exceptional circumstances, such as peculiar excellence of the staple. At the same time, cotton production has been found profitable so far as the home demand has gone, and good prices have been obtained; and when exported the California staple has rated high in comparison with the average product of the Gulf states.

What, then, are the inducements toward an expansion of cotton culture in California, and the possible establishment of cotton factories on the coast to create a home demand?

With the equalization of the prices of labor, in consequence of increased facilities of communication, there certainly is no reason why the home demand for cotton goods on the Pacific coast should not be supplied from home growth and manufacture, and there is reason why it might secure a large share of the Asiatic market, with which it is in the most direct connection.

But, it may be asked, why try to substitute a new and doubtful culture for the wheat, fruits, and wines for which California has already become famous, and of some of which it has practically a monopoly in the United States?

Apart from the general rule that the greater the variety of crops and industries of a country the more independent and the less liable it is to crop failures of a general character, there are two points that speak strongly in favor of at least the partial substitution of cotton for wheat. One is the well-known fact that wheat culture is very exhaustive of the soil, notably of the phosphates, especially when the grain is chiefly used for export, little or nothing being given back to the soil, and the same crop being repeated year after year in a wholesale fashion. It is hardly necessary to expatiate upon the fact that this kind of farming, or rather planting, is doomed to speedy termination, and that while for the time being it enriches individuals it is of very doubtful permanent benefit to the country. The exhausted wheat-fields must wait for the coming generation of more careful farmers—true husbandmen, not skinners of the soil—to be rehabilitated into something like their original productive value. That has been the history of wheat-growing all over the Atlantic states, and is certain to be repeated in California. When the wheat-fields cease to be so profitably productive as to be able to compete with the fresh lands of Washington, Montana, Dakota, and Minnesota, what crop shall be substituted for that grain? It is idle to say that there is plenty of time yet before the question arises. The truth is, that in the older settled portions of the state it is already upon us, for the average product per acre is rapidly falling from the surprising figures of old—40 and 50 bushels per acre—to the modest 12 or 15 bushels of eastern states; and it is impossible that it should be otherwise; but the man who grows 15 bushels per acre cannot long compete with those still able to grow double that amount. A portion of the lands so thrown out from wheat culture may be given to orchards and vineyards; but it will be long before these industries can occupy all the ground, if indeed the state of the world's markets would permit of their indefinite expansion. Alfalfa, which it has been proposed to substitute for grain, cannot find sufficient consumption at home, and is too bulky for export. Many other crops might be suggested that will doubtless hereafter find a profitable place in the agriculture of California, but among these there is every reason to believe that cotton will occupy a prominent place, especially since it can be grown on any naturally fairly productive soil for scores of years without thought of other manure than its own seed regularly returned to the soil. It is in this respect the reverse of the exhaustive wheat crop; for a crop of cotton lint takes no more from the soil than the chaff of the wheat would were it a merchantable article, while the grain and straw were returned to the soil.

This point is treated more exhaustively in the article on the uses of cottonseed, included in the preliminary part of this report, volume I. It is true that cotton is one of the most exhaustive crops when the seed is definitely removed, as has unfortunately been the prevailing practice in the cotton states; but it is equally true that no other crop now known is so little exhaustive as cotton when the seed and stalks are returned. This is more especially important, in view of the fact, apparent from the analyses heretofore given, that while as a whole the soils of the state are unusually rich in potash, their average content of phosphoric acid is far from large. Their abundant yields are due to their large supply of lime, through the agency of which the plant-food contained in them is made quickly available. But while it is true that calcareous soils are particularly thrifty, it is also true, and well known, that when they do become exhausted they require the most generous manuring to become productive again.

There is another reason in favor of the planting of cotton as against the planting of wheat (at least as the latter is now practiced) when irrigation is required. This is the fact (too well known to the population concerned, and more specially treated of in the article on alkali soils on pages 63 to 73) that on lands afflicted with alkali the evil is steadily on the increase, on account of the "rise of the alkali", as a consequence of continued surface irrigation. The last flooding of the wheat leaves the soil with a dense crust, from which the soil-water evaporates rapidly, and which, the grain being sown broadcast, cannot be broken and the surface soil put in the condition of tilth necessary to prevent the accumulation of the alkali salts at the surface. More and more every year the "dead spots" in the wheat-fields increase, and when, on account of such failures, it ceases to be profitable, something else must be substituted, and that substitute must be a hoed crop, planted in drills, and capable of being cultivated at all times. It should, moreover, be a deep and tap-rooted crop, requiring the least amount of irrigation, on account of the depth to which its roots reach. Cotton fulfills pre-eminently both conditions. It needs and responds generously to clean and frequent tillage, and in this it would tend to fill the period of comparative idleness experienced by the California grain-grower between harvest and seeding time that for the time, being throws a large number of laboring men out of employment. By the proverbial spreading out of the work over the entire twelve months cotton serves to secure steady employment, and therefore a steady laboring class.

In one respect, too, the California cotton-grower has a great advantage over his southern competitor. The latter has to "fight the grass" throughout the season; in fact, to keep the cotton "out of the grass" is his never-ending task. In the Sacramento valley, where cotton can be grown without irrigation, weeds cease to worry the farmer after the dry season sets in if the ground has been properly attended to before. No summer showers start a new crop of grass and compact the surface into a strangling and moisture-wasting crust. If clean to the dry season, the ground remains clean, save perhaps a few large straggling weeds that can be done away with by a few strokes of the hoe in each row. There is no crab-grass to go to seed every autumn, as an earnest of the perennial renewal of the grass fight.

Finally, where irrigation is once established, it will secure a cotton crop without fail every year, instead of the often-recurring summer droughts that so frequently stunt the crop in the Mississippi valley, and the waters of the fortnightly shower, thought there to be desirable for the best success of cotton, could here be made a certainty. But, singularly enough, such treatment is found not to benefit the plant in the climate of California, so that, in comparison with some other crops, cotton culture would be economical as regards irrigation water.

Keeping all these points in view, the writer cannot but think that the wider introduction of cotton culture into California is but a question of time, and that in many respects it will serve to improve the agricultural prosperity of the state.

Chemical analyses of California soils and subsoils.

Number.	Soil title.	Locality.	County.	Depth.	Vegetation.	Insoluble residue.	Silica, soluble in Na_2CO_3.	Total insoluble residue and silica.	Potash.	Soda.	Lime.	Magnesia.	Brown oxide of manganese.	Ferric oxide.	Alumina.	Phosphoric acid.	Sulphuric acid.	Carbonic acid.	Water and organic matter.	Total.	Hygroscopic moisture.	Temperature of absorption C.°	Analyst.
	SACRAMENTO VALLEY REGION.			*Inches.*																			
563	Sacramento river alluvium.	Rancho Chico	Butte	12	White oak (*Q. lobata*), ash, sycamore, and grape-vines.	70.764	2.680	73.444	0.652	0.077	1.444	2.277	0.015	5.804	10.397	0.087	0.030	......	5.351	99.578	6.84	11.5	Jaffa.
561	Black loam soil	do	do	12	Sunflowers and alfilerilla	59.144	3.160	62.304	0.305	0.221	2.909	1.042	0.025	9.342	13.038	0.095	0.068	......	10.149	99.498	13.98	13.0	Do.
517	Brownish loam soil	Biggs' Station	do	......	Oaks	63.268	4.750	68.018	0.453	0.113	1.460	2.174	0.105	8.585	12.045	0.064	0.047	......	6.701	99.765	8.29	13.0	Do.
656	"Slickens" sediment	Yuba river	Yuba	......	Cottonwood and willow	72.169	3.071	75.240	0.267	0.025	0.794	0.866	0.025	6.582	10.390	0.076	0.134	......	5.716	100.115	......	......	Do.
1004	do	Alger's Bend, Feather river.	Butte	......	do	61.029	8.033	69.062	0.300	0.124	0.521	0.768	0.089	6.586	14.229	0.078	0.067	......	8.024	99.848	16.09	15.0	Do.
10	Sediment soil	Sacramento river	Sacramento	12		55.283	13.940	69.223	0.353	0.065	0.901	1.249	0.111	6.316	15.251	0.250	0.097	......	6.751	100.567	......	......	Sutton.
110	Putah valley soil (middle land). (*a*)	Dixon	Solano	12	Cultivated	67.334	3.671	71.005	0.929	0.124	0.770	2.285	0.106	8.011	9.159	0.111	0.120	......	7.115	99.735	10.32	15.0	Jaffa.
	SAN JOAQUIN REGION.																						
	Alluvial or lowland soils.																						
6	Black adobe soil	S. 45, Weber grant, near Stockton.	San Joaquin	12	Scattering oaks	......	......	72.058	0.396	0.479	1.927	1.640	0.056	6.815	11.620	0.179	0.037	......	5.871	101.078	......	......	Sutton.
7	Hard-pan subsoil of No. 6	do	do	......		......	......	64.903	0.248	0.404	8.502	2.700	0.034	5.672	6.252	0.324	0.056	6.229	4.860	100.184	......	......	Do.
195	Valley soil	Merced ditch	Merced	......	Grass, herbs	75.405	8.286	83.691	0.423	0.125	0.758	0.621	0.036	4.452	6.331	0.048	0.046	......	3.882	100.415	5.48	14.5	Jaffa.
198	Merced river bottom soil (*a*)	Hopeton	do	......	Sunflowers; some oaks and cottonwood.	73.120	3.882	77.002	0.569	0.094	1.316	0.547	0.036	9.078	5.090	0.132	0.094	......	5.991	99.949	5.67	......	Do.
701	Dry bog soil (*a*)	Sisson's ranch	Tulare	......	Mostly grasses	67.519	4.259	71.778	0.562	0.657	2.599	0.753	0.066	5.599	12.395	0.074	0.145	0.083	4.495	99.306	11.19	15.0	Do.
585	"Wire-grass" soil (*a*)	Visalia	do	......	White oak, wire, and alkali grass; alfilerilla.	66.470	4.950	71.420	1.224	0.677	3.043	0.087	0.030	5.823	7.137	0.239	0.655	2.546	7.091	99.972	8.53	15.0	Do.
570	Brown adobe soil (*a*)	Eisen vineyard	Fresno	......		76.622	2.870	79.492	0.714	0.444	1.769	2.048	0.041	3.728	7.988	0.038	0.074	......	3.244	99.580	5.43	......	Do.
579	Alluvial loam soil (*a*)	Grangeville, Mussel slough.	Tulare	12	Wild flowers; grass	79.518	3.219	82.737	0.700	0.286	1.246	1.578	0.018	4.030	6.578	0.069	0.019	......	3.049	100.310	3.89	15.0	Do.
77	"Dry bog" soil	Tulare lake	do	12	Salt-grass	......	......	67.340	1.050	0.840	6.510	3.960	0.040	5.050	7.970	0.320	0.080	4.420	3.710	101.290	......	15.0	Morse.
	Uplands or bench soils.																						
193	Loam soil (*a*)	Hog-wallow tract near Huffman's.	Merced	12	Grass, herbs	80.328	4.345	84.673	0.347	0.058	0.508	0.588	0.016	4.772	6.165	0.023	0.006	......	3.278	100.434	4.21	15.0	Jaffa.
704	Fresno plains soil (*a*)	Central colony	Fresno	12	do	85.874	2.705	88.579	0.340	0.248	1.163	0.499	0.034	3.276	3.221	0.097	0.117	......	1.789	99.363	2.22	15.0	Do.
586	Tulare plains soil (*a*)	East of "Outside creek"	Tulare	12	Wild flowers, grass	73.774	3.491	77.265	1.221	0.149	1.173	1.751	0.027	5.673	7.799	0.103	0.003	......	4.351	99.515	4.62	15.0	Do.
573	do	Cross creek	do	12	do	66.079	3.378	69.457	1.817	0.436	4.307	1.585	0.078	6.041	8.692	0.138	0.263	2.533	4.150	99.497	8.74	15.0	Do.
700	Salt-grass soil (*a*)	Buena Vista slough	Kern	12	Salt-grass	87.060	1.980	89.040	0.492	0.305	1.198	1.069	0.025	5.822	0.171	0.079	0.133	......	1.130	99.464	2.16	15.0	Do.
	FOOT-HILL REGION.																						
559	Red-loam soil	Redding station	Shasta	......	Scattering oaks	76.274	4.102	80.376	0.500	0.041	0.104	0.403	0.009	6.686	8.480	0.036	0.012	......	3.968	100.615	5.05	15.0	Do.
705	Red chaparral soil	Anderson	do	12	Chaparral, poison oak, small oaks, and brush.	63.384	5.480	68.864	0.417	0.052	0.288	0.207	0.037	7.705	14.443	0.047	0.074	......	7.680	99.814	10.00	15.0	Do.
706	Red chaparral subsoil	do	do	12–22	do	63.194	4.710	67.904	0.467	0.044	0.327	0.350	0.029	6.263	17.434	0.064	0.043	......	7.229	100.154	10.75	15.0	Do.

a Soils analyzed at expense of United States Census Office; all others at the laboratory of the College of Agriculture, University of California.

Chemical analyses of California soils and subsoils—Continued.

Number.	Soil title.	Locality.	County.	Depth.	Vegetation.	Insoluble residue.	Silica, soluble in Na_2CO_3.	Total insoluble residue and silica.	Potash.	Soda.	Lime.	Magnesia.	Brown oxide of manganese.	Ferric oxide.	Alumina.	Phosphoric acid.	Sulphuric acid.	Carbonic acid.	Water and organic matter.	Total.	Hygroscopic moisture.	Temperature of absorption C.°	Analyst.
	FOOT-HILL REGION—continued.			*Inches.*																			
499	Red upland loam soil	Wheatland	Yuba	......	Herbs; scattered poison-oak.	78.789	3.803	82.592	0.249	0.035	1.021	0.471	0.018	5.811	6.283	0.043	0.019	......	3.644	100.186	4.81	15.0	Jaffa.
51	Red foot-hill soil	Auburn	Placer	12	Oak, pine, and chaparral.	......	......	69.520	0.380	0.070	0.960	1.090	0.390	12.420	10.970	0.160	0.010	......	5.140	101.110	.....	15.0	Morse.
67	Mining slum soil	Near Chinese camp	Tuolumne	......	Willows, grass	......	......	72.980	0.190	0.210	1.190	2.320	0.080	9.300	10.550	0.080	0.030	......	4.430	101.360	.....	....	Do.
68	Valley "adobe" soil	do	do	......	Oaks	......	......	56.610	0.190	0.140	0.680	13.740	0.080	18.430		0.070	0.010	......	9.840	99.790	.....	....	Do.
190	Red-loam soil	Lagrange	Stanislaus	12	"Blue" and white oaks, poison-oak, grass, and flowers.	67.915	6.964	74.879	0.352	0.126	1.544	0.720	0.031	7.879	9.864	0.091	0.362	......	3.766	99.614	5.42	15.0	Jaffa.
191	Red foot-hill soil	Merced Falls	Merced	10	Grass and "blue" oaks.	73.352	4.506	77.858	0.375	0.125	0.351	0.840	0.066	6.964	8.804	0.067	0.221	......	5.060	101.731	6.11	15.0	Do.
196	Red gravelly soil	Hog-wallows, 11 miles north of Merced.	do	8	Grasses	79.078	5.544	84.622	0.208	0.111	0.394	0.361	0.033	3.903	6.660	0.053	0.082	......	4.143	100.570	4.97	15.5	Do.
	SOUTHERN REGION.																						
332	Mojave desert soil	Mojave station	Kern	12	Sage-brush, creosote plant, grass.	70.965	4.999	75.964	0.928	0.078	1.787	1.782	0.026	5.478	9.227	0.056	0.012	0.456	3.903	99.697	10.76	15.0	Do.
130	Bench-land soil	San Gabriel valley	Los Angeles	......	Grasses	......	......	81.120	0.270	0.170	0.680	1.770	0.100	6,300	6.790	0.160	0.070	......	3.070	100.500	2.30	15.0	Morse.
382	Low mesa soil	Pomona	do	12	Grass, alfilerilla	72.519	5.121	77.640	0.839	0.296	2.954	2.225	0.039	8.097	5.974	0.018	0.022	......	2.550	100.054	3.46	15.0	Do.
381	Low mesa subsoil	do	do	12–32		75.304	3.872	79.176	0.962	0.301	2.052	2.154	0.043	7.342	5.835	0.049	0.020	......	2.546	100.480	2.37	15.0	Do.
47	Mesa land soil	National ranch	San Diego	......	Grass, herbs	......	......	86.210	0.480	0.140	0.360	0.540	0.100	3.690	5.120	0.230	0.030	......	2.600	99.500	2.30	15.0	Do.
506	Bottom soil (*a*)	Colorado river	do	12	Mezquite trees, creosote plant, and arrow weed.	58.574	5.327	63.901	1.177	0.162	8.671	2.966	0.025	4.139	8.379	0.133	0.145	7.818	3.344	100.860	9.26	15.0	Jaffa.
	COAST RANGE REGION.																						
	South of San Pablo bay.																						
168	Valley soil (*a*)	Santa Paula	Ventura	12	......	85.664	1.847	87.511	0.634	0.070	0.759	0.593	0.025	3.350	3.095	0.200	0.003	......	3.132	99.372	5.49	15.0	Do.
182	Reddish mountain soil	do	do	12	Grass, herbs	74.930	7.912	82.842	0.621	0.164	0.952	0.955	0.036	5.070	5.939	0.127	0.039	......	2.669	99.414	6.59	15.0	Do.
170	Bench-land subsoil	Hollister's ranch	Santa Barbara	12–18	Oaks	83.065	4.678	87.743	0.506	0.058	0.561	0.666	0.055	3.116	2.995	0.223	0.094	......	3.854	99.871	5.98	15.0	Do.
600	Upland soil	"Poverty Hill"	San Benito	12	Cultivated twelve years.	85.596	2.567	88.163	0.333	0.109	0.676	0.526	0.048	2.856	4.214	0.027	0.015	......	3.476	100.443	5.22	12.5	Do.
606	Upland loam soil	Soquel ranch	Santa Cruz	12	Cultivated	80.426	3.028	83.454	0.343	0.126	0.502	0.390	0.014	3.928	5.711	0.053	0.009	......	4.955	99.485	5.60	15.0	Do.
702	Chaparral soil	Two miles northeast of Saratoga.	Santa Clara	12	......	57.449	5.114	62.563	0.859	0.260	1.987	2.428	0.098	10.019	9.516	0.139	0.063	......	11.921	99.853	12.09	15.0	Do.
37	Valley soil	Pescadero	San Mateo	......	Redwood, pine, oak, alder, buckeye, and madrone.	78.084	3.237	81.321	0.541	0.231	0.925	0.820	0.039	4.934	4.821	0.084	0.027	......	6.757	100.500	7.38	15.0	Do.
680	Sandstone soil	San Francisco	San Francisco	8	Scrubby live-oak	78.135	3.458	81.593	0.675	0.080	0.846	0.780	0.053	5.682	5.162	0.031	0.053	......	5.404	100.359	6.02	15.0	Morse.
682	Sandstone subsoil	do	do	8–18	......	70.224	5.532	75.756	0.590	0.172	0.399	1.221	0.059	7.268	9.737	0.011	0.022	......	4.900	100.135	9.41	15.0	Do.
643	Black waxy adobe soil	Colton ranch	Contra Costa	12	Sunflower	50.960	9.020	59.980	0.192	0.741	2.471	0.890	0.065	11.090	15.689	0.057	0.045	Trace	8.304	99.524	13.51	15.0	Do.
592	Dark soil, rolling uplands.	Livermore valley	Alameda	6	Scattering white oak and poison-oak.	80.262	5.023	85.285	0.299	0.108	0.813	0.647	0.065	3.584	4.933	0.006	0.010	......	4.047	99.857	5.67	15.0	Jaffa.
693	Dark subsoil, rolling uplands.	do	do	6–18		80.658	5.157	85.815	0.357	0.121	0.693	0.666	0.025	3.647	5.329	0.062	0.008	......	3.435	100.158	6.12	15.0	Do.
594	Red gravelly soil, rolling uplands.	do	do	8		81.941	3.756	85.697	0.323	0.081	0.720	0.562	0.030	3.6[illegible]0	5.540	0.061	0.008	.....	3.550	100.193	4.53	15.0	Do.

649	Sediment soil	Arroyo del Valle, Livermore valley.	Alameda		Shrubs, herbs, and some sycamores.	71.156	4.938	76.094	1.143	0.123	2.049	3.046	0.044	5.648	7.153	0.117	0.101	1.004	3.679	100.201	5.67	15.0	Do.
1	Black "adobe" soil	University grounds	do	12–22	Live-oaks, large			77.844	0.452	0.074	1.050	1.211	0.078	4.675	7.788	0.231	0.077		5.718	99.198		15.0	Sutton.
2	Subsoil of No. 1	do	do	22–30	do			69.563	0.348	0.109	0.998	1.913	0.093	7.208	13.970	0.116	0.028		6.600	100.946			Do.
4	"Adobe" ridge subsoil	do	do	10–20	Scattered live-oak, small			86.002	0.189	0.154	0.484	0.452	0.033	4.013	5.532	0.057	0.021		4.051	100.993			Do.
	North of San Pablo bay.																						
185	Valley soil	G. F. Hooper's vineyard	Sonoma	12	Oaks and grape-vines	76.089	6.839	82.928	0.435	0.123	0.744	0.578	0.025	5.793	5.092	0.187	0.171		3.715	99.791	4.98	15.0	Jaffa.
188	Red mountain soil	do	do	12	Oaks, manzanita, chaparral.	34.392	14.110	48.502	0.319	0.058	0.670	0.712	0.146	25.955	12.160	0.166	0.274		11.640	100.602	13.71	15.0	Do.
207	Eel river bottom soil	3 miles east of Ferndale	Humboldt	12		65.346	6.896	72.242	1.127	0.282	0.105	3.329	0.117	6.986	10.236	0.167	0.020		5.629	100.240	7.87	15.0	Do.
205	Subsoil of No. 207	do	do	12–25		69.373	3.588	72.961	1.134	0.120	0.101	3.239	0.054	7.307	9.758	0.141	0.026		4.665	99.506	6.21	15.0	Do.
676	Red volcanic soil	Flat on Clear lake	Lake	12	Not known	49.604	5.934	55.538	0.452	0.170	0.658	0.610	0.051	10.477	22.585	0.031	0.033		9.654	100.259	11.11	15.0	Morse.
672	Gray valley soil	2 miles south of Saint Helena.	Napa	12	Large white oak	77.017	3.340	80.357	0.746	0.477	0.600	1.331	0.041	5.656	5.671	0.101	0.050		5.252	100.282	4.50	15.0	Do.

a Soils analyzed at expense of United States Census Office; all others at the laboratory of the College of Agriculture, University of California.

Table of humus and its available constituents (percentages referred to the soils) found in California soils.

No.	Name.	Locality.	County.	Humus.	Available inorganic.	Available phosphoric acid.
563	Sacramento river alluvium	Rancho Chico	Butte	0.749	0.255	....
517	Brownish loam soil	Biggs' Station	....do	1.184	0.464	....
110	Putah valley (middle land), cultivated	Dixon	Solano	1.709	0.562	....
195	Valley soil	Merced ditch	Merced	0.867	0.595	....
198	Merced river bottom soil	Hopeton	....do	1.800	0.563	0.130
701	Dry bog soil	Sisson's ranch	Tulare	1.061	0.984	0.039
570	Brown adobe soil	Eisen vineyard	Fresno	0.597	0.373	0.020
579	Alluvial loam soil	Grangeville, Mussel slough	Tulare	0.644	0.587	....
77	Dry bog soil	Tulare lake	....do	0.468	2.184	....
193	Loam soil	Hog-wallow tract near Huffman's	Merced	0.367	0.334	0.010
704	Fresno plains soil	Central colony	Fresno	0.604	0.351	0.011
586	Tulare plains soil	East of Outside creek	Tulare	1.139	0.535	....
578	Tulare plains soil	Cross creek	....do	0.996	0.740	....
700	Salt-grass soil	Buena Vista slough	Kern	0.170	0.196	0.009
705	Red chaparral soil	Anderson	Shasta	1.420	....	....
499	Red upland loam soil	Wheatland	Yuba	0.466	0.336	....
51	Red foot-hill soil	Auburn	Placer	1.140	1.120	....
67	Mining-slum soil	Near Chinese camp	Tuolumne	0.420	0.360	....
68	Valley adobe soil	......do	....do	1.614	0.395	....
190	Red-loam soil	Lagrange	Stanislaus	0.715	0.448	....
191	Red foot-hill soil	Merced Falls	Merced	0.712	0.407	....
196	Red gravelly soil	Hog-wallows 11 miles north of Merced	....do	0.758	0.533	....
332	Mojave desert soil	Mojave station	Kern	0.283	0.370	....
382	Low mesa soil	Pomona	Los Angeles	0.324	0.263	....
47	Mesa land soil	National ranch	San Diego	0.555	1.439	....
506	Bottom soil	Colorado river	....do	0.752	1.151	0.133
168	Valley soil	Santa Paula	Ventura	0.841	0.368	0.200
182	Reddish mountain soil	......do	....do	1.055	1.004	....
170	Bench-land subsoil	Hollister's ranch	Santa Barbara	1.341	0.271	....
600	Upland soil	Poverty hill	San Benito	0.819	0.284	....
606	Upland loam soil	Soquel ranch	Santa Cruz	1.463	0.579	....
37	Valley soil	Pescadero	San Mateo	2.850	0.625	....
702	Chaparral soil	Near Saratoga	Santa Clara	3.096	0.884	....
680	Sandstone soil	San Francisco	San Francisco	2.284	1.045	....
1	Black adobe	Berkeley	Alameda	1.750	....	....
643	Black waxy adobe soil	Colton ranch	Contra Costa	1.500	0.829	0.036
649	Sediment soil	Arroyo del Valley / Livermore valley	Alameda	0.396	0.413	....
185	Valley soil	Hooper's vineyard	Sonoma	1.111	0.371	....
188	Red mountain soil	......do	....do	2.537	1.171	....
207	Eel river bottom soil	East of Ferndale	Humboldt	1.250	0.590	....
205	Eel river bottom subsoil	......do	....do	0.652	0.427	....
676	Red volcanic soil	Flat on Clear lake	Lake	1.442	0.393	0.014
672	Gray valley soil	Two miles south of Saint Helena	Napa	1.685	0.457	....

MECHANICAL COMPOSITION OF CALIFORNIA SOILS.—The mechanical analyses thus far made of California soils are given in the table on page 83. The method of analysis was that described by the writer in 1873 (*a*), by the aid of the elutriator or soil-washer, devised for the purpose, and constructed for the University of California. Many important points of general interest are deducible from these analytical results, but their detailed discussion would lead beyond the limits necessarily assigned to the present report. Attention should, however, be called to some typical soils. Thus, soil No. 586 is fairly representative of the "plains soils" of the San Joaquin valley, with the exception of the Fresno region, showing that while these soils, on account of the coarseness of a large part of their mass, appear very sandy, yet they contain as much clay as would usually constitute a "light loam". Again, Nos. 1, 2, 6, and 110 exemplify the ordinary "black adobe" of the Coast range and great valley, modified in opposite directions in the cases of Nos. 8, 9, and 68, which are lighter; and No. 643, which is heavier than the average, the latter, in fact, becoming, like the "hog-wallow" of Mississippi (see report on that state), almost unmanageable under ordinary circumstances. No. 168 is the remarkable soil which allows an ax-handle to be pushed down to the head or the arm to the elbow without exertion, yet is so retentive of moisture as to need no irrigation. It does not differ widely in most respects from No. 51, the red foot-hill soil from Auburn, which, like the other, is found to be so admirably adapted to fruit-growing. Nos. 47 and 130 exemplify well the light loam soils of the southern region, on which the vine will grow without and other fruits with but little irrigation. The Colorado river bottom soil might be expected to be a somewhat heavy loam, but its large percentage of lime places it among the light loams. Again, between Nos. 8 and 9, one alkaline, the other not, the difference in mechanical composition is but slight, whereas, in consequence of alkali, No. 9 is practically untillable. These facts are referred to in the text in connection with the description of the several soils.

a *Am. Jour. Sci.*, Oct. and Nov., 1873; Jan., 1874.

Mechanical analyses of California soils and subsoils.

	ENTIRE SOIL.				FINE EARTH.												
	Weight of stones over 1.2 mm.	Weight of stones between 1.2 and 1 mm.	Weight of stones between 1 and 0.6 mm.	Fine earth.	Clay.	Sediment of <0.25 mm.	Sediment of < 0.25 mm.	Sediment of < 0.5 mm.	Sediment of < 1.0 mm.	Sediment of < 2.0 mm.	Sediment of < 4.0 mm.	Sediment of < 8.0 mm.	Sediment of < 16.0 mm.	Sediment of < 32.0 mm.	Sediment of < 64.0 mm.	Total.	Analyst.
No. 10.—Sediment soil, Sacramento river, near Sacramento.	None.	None.	None.	....	12.062	36.682	6.927	13.111	13.665	10.267	3.163	0.322	......	......	......	96.199	Sutton.
No. 6.—Black "adobe" soil, S. 45, Weber grant, near Stockton, San Joaquin county.	None.	....	0.360	99.650	32.625	37.115	4.304	5.501	5.617	2.013	1.982	3.1450	2.106	1.285	0.437	96.130	Do.
No. 8.—Non-alkaline soil from Overhiser's, near Stockton, San Joaquin county.	0.400	....	1.610	97.990	20.800	32.000	8.300	6.600	5.600	7.300	7.500	5.700	4.800	1.500	1.200	96.400	Do.
No. 9.—Alkaline soil from Overhiser's, near Stockton, San Joaquin county.	0.550	....	2.140	97.310	24.600	26.100	3.300	9.400	6.200	6.200	5.400	4.800	4.700	5.900	1.100	97.700	Do.
No. 77.—"Dry bog" soil, southeast shore of Tulare lake.	....	4.100	....	95.900	29.793	18.840	1.567	2.195	8.183	8.622	9.722	6.641	2.115	2.407	1.275	a86.360	Morse.
No. 586.—Tulare plains soil, "Outside" creek, Tulare county.	....	....	....	....	10.481	23.119	1.329	2.155	10.644	6.151	7.907	7.646	7.991	11.112	8.686	97.221	Jaffa.
No. 51.—Red foot-hill soil, Auburn, Placer county.	....	13.042	....	86.058	13.911	28.963	2.941	5.570	11.392	15.953	10.454	3.516	1.121	0.265	0.161	94.247	Morse.
No. 67.—Mining slum soil near Chinese camp, Tuolumne county.	....	1.850	....	98.150	18.474	27.270	0.906	8.196	10.563	11.975	9.228	6.608	1.240	0.873	0.824	96.157	Do.
No. 68.—Valley "adobe" soil near Chinese camp, Tuolumne county.	25.330	5.804	4.749	64.116	26.100	35.580	0.835	3.987	4.791	5.974	4.450	5.440	4.229	2.877	3.202	97.465	Do.
No. 130.—Bench-land soil, San Gabriel valley, Los Angeles county.	7.720	4.730	5.070	82.470	10.700	16.320	1.330	6.590	5.020	7.090	13.100	8.390	10.050	11.390	7.550	97.530	Do.
No. 47.—Mesa-land soil, National ranch, San Diego county.	9.760	9.110	10.330	70.800	9.660	10.370	0.970	3.240	3.820	5.900	8.360	12.860	13.540	17.730	12.570	b99.020	Do.
No. 506.—Bottom soil, Colorado river, San Diego county.	....	....	....	....	23.969	30.909	0.790	11.278	12.640	8.382	2.513	0.752	0.107	0.147	0.181	c91.708	Jaffa.
No. 108.—Valley soil, near Santa Paula, Ventura county.	....	3.530	....	96.470	15.020	14.040	1.200	5.140	8.030	12.670	16.360	11.480	7.010	6.450	4.110	b101.510	Morse.
No. 1.—Black "adobe" soil, university grounds, Alameda county.	13.945	6.567	....	79.498	31.930	24.600	1.170	3.400	4.770	7.490	6.200	0.870	2.780	7.060	5.440	96.310	Sutton.
No. 2.—"Adobe" subsoil, university grounds, Alameda county.	35.275	7.793	....	56.932	33.530	22.120	6.030	5.940	7.000	6.420	7.930	3.990	1.840	0.210	0.020	95.030	Do.
No. 4.—"Adobe" ridge soil, university grounds, Alameda county.	13.233	4.607	....	82.160	18.920	17.250	4.870	6.790	6.420	6.640	3.690	7.450	11.030	9.490	3.420	95.970	Do.
No. 188.—Reddish mountain soil, G. F. Hooper's vineyard, Sonoma county.	....	....	....	....	d52.242	14.685	1.053	4.877	6.096	3.605	5.090	4.368	3.275	1.047	0.449	96.787	Jaffa.
No. 110.—Valley soil, Putah creek, Solano county.	....	....	....	....	31.490	43.080	2.270	3.560	4.970	4.400	2.640	1.500	1.300	......	......	95.210	Morse.
No. 643.—"Adobe" soil, mount Diablo, Contra Costa county.	....	3.200	....	96.800	43.540	34.050	1.590	2.590	3.130	2.790	2.260	1.760	0.750	......	2.230	94.690	Do.
No. 676.—Red-land soil, Lake county.	....	30.320	....	69.680	e29.840	29.950	1.440	3.730	6.060	6.020	5.970	5.380	3.880	4.070	2.130	98.470	Do.

a The low summation of this analysis is due to the dissolution of lime and some alkaline salts in the large quantity of water employed, the clay at first failing altogether to diffuse until these salts had been washed out. *The loss bears mainly, of course, upon the fine sediments.*

b This high summation is probably, to some extent, due to the turbidity of the water used for analysis, which added to the weights of the finest sediments.

c Low summation due to solution of lime salts.

d Containing about 25.0 of ferric hydrate.

e Containing about 11.0 of ferric hydrate.